RADC-TDR-62-472

ENGINEERING ANALYSIS AND DIGITAL SIMULATION OF THE OPTICAL RUSSIAN PRINT READER

COMPUTER SET, GENERAL INFORMATION DATA AN/GSQ-16 (XW-2)
(RUSSIAN-ENGLISH TRANSLATOR)
CONVERTER GROUP, PRINT-TO-DIGITAL AN/GSA-29

TECHNICAL DOCUMENTARY REPORT NO. RADC-TDR-62-472
September 3, 1962

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Research and Technology Division
Air Force Systems Command
Griffiss Air Force Base, New York

Project No. 4599, Task No. 459902

(Prepared under Contract AF30(602)-2080 by the
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FOREWORD

This report is intended to document the state of development of Converter Group, Print-To-Digital AN/GSA-29 at the completion of Task 14 of Contract AF 30(602)-2080. The primary objectives of the work under this task was the evaluation of the line following system and masking technique.

The entire work assignment was performed at the Thomas J. Watson Research Center and was carried out in the Experimental Systems Research Department.

ABSTRACT

The Optical Russian Print Reader (Converter Group, Print-To-Digital AN/GSA-29) has been assembled, the front end optics aligned, and the line following servo system analyzed with the assistance of Baird-Atomic personnel. An IBM 7090 simulation shows that the basic masking technique used for an idealized electro-optical system yields adequate discrimination levels only for very high quality characters and for very close tolerances on text registration. The report contains a detailed description of the servo analysis and masking technique simulation; it also includes error rate tabulations based on input text quality and proposed mask alterations.

PUBLICATION REVIEW

This report has been reviewed and is approved.

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ENGINEERING ANALYSIS AND DIGITAL SIMULATION OF THE OPTICAL RUSSIAN PRINT READER

INTRODUCTION

An analysis of the line following servo system and masking technique used in the Optical Russian Print Reader (Converter Group, Print-To-Digital AN/GSA-29) has been made. The line following servo system was statically tested and its operation also simulated. The masking technique was simulated using an IBM 7090 computer with digitalized characters. The simulation was also used to investigate the effect of mask alterations proposed to decrease the system sensitivity to character misalignment. The overall simulation results have been used to predict a lower limit on the error rate and to relate this error rate to character area changes, misregistration, and some system noise.

SUMMARY:

1. The design and action of the line follower appears to be adequate for "good" text.*
2. With excellent quality characters properly registered on original documents the character discrimination would be sufficient so that it should be within the state of the art to design an optical system and an analog computer to differentiate between characters with a high degree of reliability. However, the major limitation of this character recognition technique is the quality of the source document; this quality being indicated by character area stability, shape stability and individual vertical registration.

BACKGROUND

The equipment (Converter Group, Print-To-Digital AN/GSA-29) was assembled by Baird-Atomic personnel and the front end optics aligned to permit operation of the line follower (Fine Positioning Servo System).

An IBM 7090 computer simulation was used rather than the partially completed system for analyzing the character masking technique for the following reasons:

1. The quality of the text could be controlled as to area dropout or addition and vertical registration.
2. The system variables could be bypassed such as:
   (a) Image distortion from main optical path.
   (b) Photomultiplier tube (PMT) and amplifier drift.
   (c) Alignment of 112 lens array for given mask.
   (d) Mechanical vibrations.
3. The proposed vertical mask expansion (slurring) to reduce vertical sensitivity could be easily simulated.

The use of the computer simulation also predicts the upper bound on descrimination levels for the tested Type font A† and allows a prediction of the system tolerances and text limitation.

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*"good" text meaning:
"Text with input characters which deviate from their respective masks by less than a few per center in total area imprinted and general shape, and which are aligned from character to character to within 3% of their reference position."

†Bosi, C. et. al. "Russian Type Study", Technical Note 1, New York University, Division of General Education, Sponsored by RADC, Contract AF 30(602) – 1824, November 15, 1958.

CHARACTER DIGITALIZATION

The use of an IBM 7090 computer for the simulation of the character recognition masking technique necessitated converting the character shapes into a digitalized format. The binary coding 0-1 was used to signify by 0 the absence, and by 1 the occurrence of character area at a fixed location. The location size was chosen to be a square 0.00209 inch on a side when referenced to the original document. The narrowest stroke occurring in the Type font A is approximately 0.004 inch wide and would be represented by two binary bits. The binary bit size of 0.00209 inch at the original document corresponds to a resolution of 9.5 line pairs per millimeter which is about two times better than the optical resolution in the system as it is now and about equal to a reasonable design resolution.

The character digitalization was accomplished by obtaining 96 × blowups of the Russian characters from Type font A (Figure 1). The original photographs of the characters were prepared by Baird-Atomic from many samples and were used in preparing the type font masks.*

The 96 × character photographs to be digitalized were overlaid with a 72 × 72 transparent grid with the established base reference line above bit position number 22 of the even numbered words as shown in the above figure. Each character was also positioned so that some character area was shown as information in either Word #1 or Word #2. Each word is 36 bits long and the maximum field for any character is 144 words. The card punching format was as follows:

Columns:	1 - 3	Decimal Character Number
	4 - 6	Blank
	7 - 18	Octal Data (second word)
	19 - 30	Octal Data (first word)
	31 - 77	Blank
	78 - 80	Decimal Card Number

The resolution of this grid size is shown in Figure 3.

Since the card punching was in an octal basis, the computer program was written to convert the data to binary form for analysis. A binary printout of the digitalized characters has been made and is shown in Parts 1 thru 3 of the data printout book.† The stars represent where the character area filled the reference square by more than 50%; that is, each star represents a 0.00209 inch square of character area (See Page 22). The star printout appears vertically compressed due to the difference between line spacing and character spacing in the IBM 717 printer. The printouts of Parts 1 thru 3 also list the area of the character as "total number of bits in grid", with each bit again being a 0.00209 inch square at the original document.

Definitions:

Match – The value $2P - (P + N)^{\ddagger}$ normalized by the true area of the reference character.

Auto-correlation – The match value when the indicated input character and reference character are identical.

Cross-correlation – The match value when the indicated input character occurs in the listed reference character channel.

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*It should be noted that the reference to "perfect" characters and "perfect" mask to be used herein refers to the Baird-Atomic photographs. The variation of size or shape in any given character has been eliminated by using the same digitalized characters as both the input and the reference masks.

†The printout of the digitalized characters represent Parts 1 thru 3 of the data printout book, with Parts 4 thru 8 the simulation runs. The data book is 1287 pages long, and is being retained at the IBM Research Center. Examples of the type of data obtained have been included and are shown on Pages (22 thru 45.)

‡See Page 9.

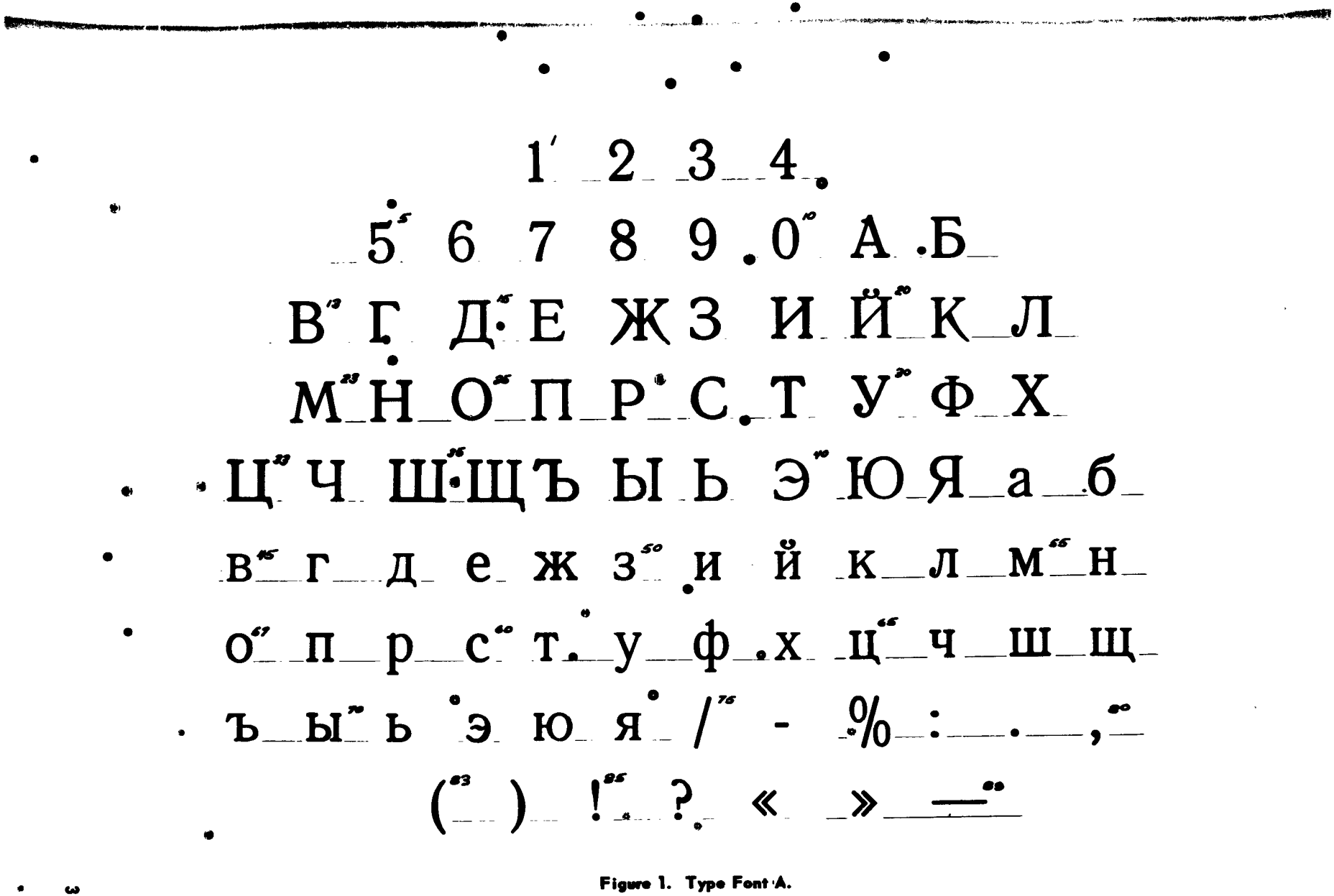


Figure 1. Type Font A.

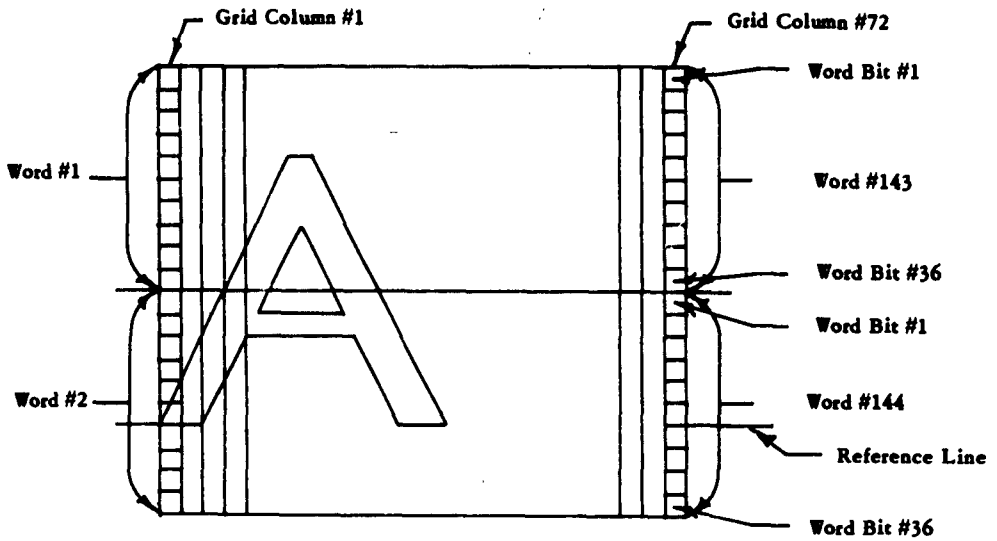


Figure 2. Character Digitalization.

LINE FOLLOWER

The purpose of the line follower is to establish a base line for proper vertical alignment of the characters on the type font masks. The recognition system, as designed, is critically sensitive to input vertical alignment on the positive character masks. The vertical sensitivity to alignment was shown by the IBM 7090 character simulation as an inability for the recognition technique to maintain discrimination between similar characters. It has been found that a vertical displacement of ±0.00209 inch referenced back to the original document is troublesome. This vertical displacement of ±0.00209 inch represents about 3% of the height of a lower case character and about 2% of the height of an uppet case character. This therefore puts the stress on line following servo to maintain adequate discrimination levels.

The line following servo, as presently designed by Baird-Atomic, establishes an average base line for 14 character spaces. The servo system must be capable of film positioning to within ±0.00094 inch to maintain a ±0.00209 inch tolerance referenced back at the document.

The decision time for character recognition is less than 25 microseconds meaning that the line servo does not have time to position each character individually during the decision period (400 cps servo with 160 cps reported band-width implies a 6.25 milliseconds response time for error detection and correction).

The mis-alignment of any given character in any line would only be partially corrected by the averaging of the line follower.

The given film samples represent a reduction of a 5 inch wide column of printed material in Type font A. The 5 inch column represents the maximum allowable width and has approximately 66 character spaces per line. The 11 lines per second designed operation gives a document scanning speed of 88.3 inches per second (after correcting of dwell, flyback and idle times). This therefore represents 23.4 microseconds per 0.00209 inch (23.4 microseconds per bit).

The character which is to be recognized has to move 9.8 character spaces from the center of the line follower window to the recognition position. The movement takes 8.2 milliseconds during which the servo may only possibly make one correction.

The decision time of 25 microseconds is determined from the IBM 7090 simulation where the auto-correction function reaches its normalized peak of 1.00 and, in all cases, only remains at this peak for one bit space or 0.00209 inch on the original document.

Upper – 8 x blowups Lower – actual size
Left – actual character Right – digitalized character

Figure 3. Character #17, Actual and Digitalized.

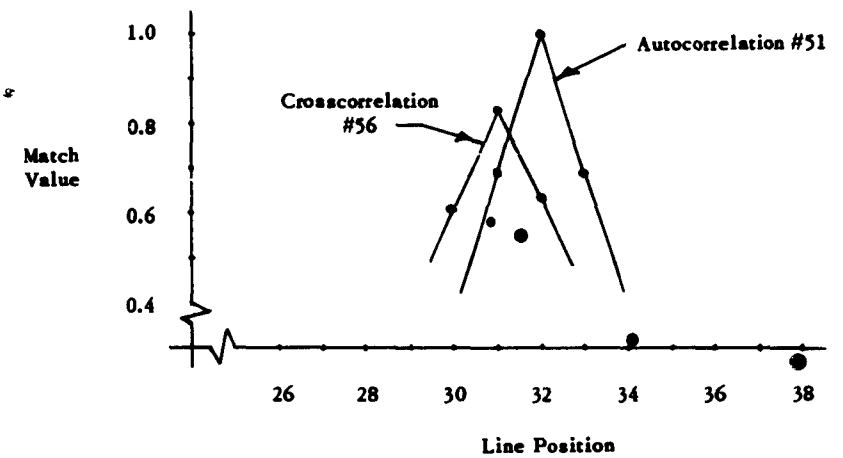


Figure 4. Channel #51 Response.

As an example, it can be clearly seen that the threshold firing value for the H recognition channel must be above 0.83 as this is the maximum cross-correlation normalized match value reached by input character #56 H (See Page 26). This threshold value is not uniquely determined for all characters, but is dependent on the highest cross-correlation obtained for each reference character.

It is advantageous to have the threshold value as close as possible to the highest cross-correlation in order to obtain as much insensitivity to vertical displacement as possible.

Thus, in the cited case, the auto-correlation for character #51 drops to 0.77 when the input is shifted ±1 bit vertically; that is, 0.00209 inch vertically displaced from the reference line established by the line servo when referenced back at the original document.

The auto-correlation then drops to 0.57 for a ±2 bit vertical shift. These latter values are below the cross-correlation obtained from character #56 in #51 channel. This means that it is necessary to at least maintain better than ±1 bit vertical alignment for recognition of this character.

The Fine Positioning Servo System (Line Follower) analysis was accomplished by a static operational test of the system and by also simulating the operation by use of the digitalized characters.

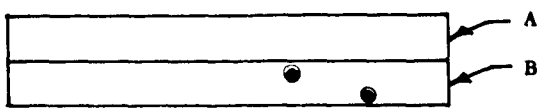
The experimental analysis was limited in usefulness due to the uncertainty of measured results. This uncertainty in test results was due to the following:

1. The image quality at the measuring reticle was very poor due to the system optics.
2. The light level was relatively low, which made the taking of measurements a very fatiguing job.
3. The film used for the test was of good quality, but the typographical errors of misalignment of the original text was an uncontrolled parameter.
4. The positioning servo was operated statically and no measure of its dynamic operation was possible.

By assuming a normal distribution for the data obtained on 69 lower case letters, it is estimated that approximately ten per cent of all characters will fall outside the range of plus or minus 0.002 inch from their mean position. Approximately one per cent of the characters will fall outside the range of plus or minus 0.003 inch from their mean position.

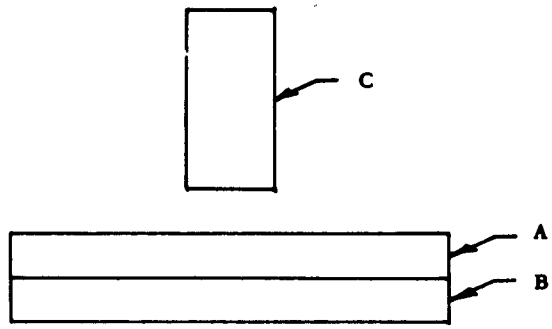
It is felt that this measure of character misregistration is mainly due to the original document variations.

The line follower action is as follows. A narrow slit approximately 14 character spaces in length is divided into two equal parts optically (A and B below). Each area is examined for total

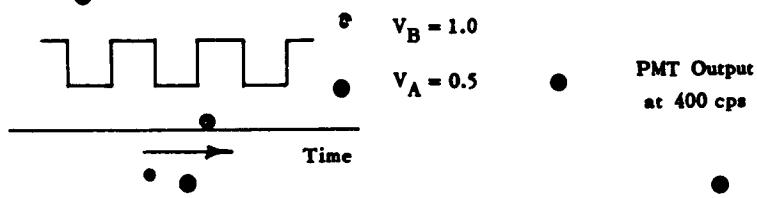


light level in turn by the same photo-multiplier tube (PMT) through a 400 cycles-per-second rotating optical chopper assembly. The characters are clear areas on the film, (white on black) so that each character is represented by a lighted area on a dark background. The light level in area A is reduced by a factor of 0.5 by means of a neutral density filter and sensed by the PMT. The light level in area B is then sensed by the same PMT. The sampling is synchronous with a 400 cps reference source, so that each sample area is shown relative to the reference timing. The difference in PMT voltage levels (if present) is sensed and used as the feedback signal (error detection) for the film positioning. The film is continuously positioned until the PMT signals are equal.

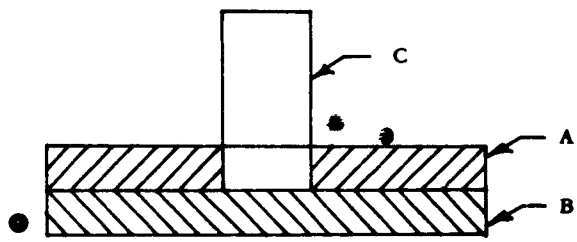
An example of this is shown by using a lighted bar (C) and the two areas A and B.



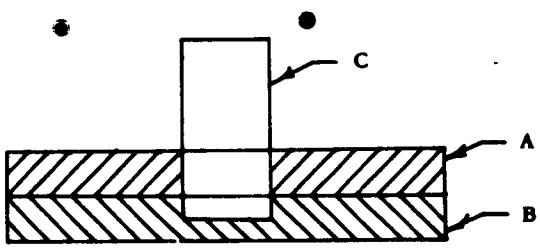
The PMT output signals will be examined. With equal total illumination on A and B and keeping in mind the 0.5 light reduction of the signal in A, the PMT signal may be normalized to $V_A = 0.5$ and $V_B = 1.0$.



As the film (with bar C) enters the gate, the otherwise non-illuminated areas A and B receive light.



The illumination of the slits first occurs in A and the size of C will be assumed to cover 20% of A. The V_A output signal will therefore be 0.1 (0.5 x 0.2), while V_B remains at 0 due to its non-illumination. The signal difference is detected and used to advance the servoing of the film (and area C) until the position shown below is reached.



The area of C in A is still 20%, giving a V_A PMT signal of 0.1 and the area of C in B is 10% giving a V_B PMT signal of 0.1 also. The error detection and correction signal is 0 and the servo holds the film stationary.

The descent of C causes V_B to exceed V_A and the servo to raise the film, and the ascent of C causes V_A to exceed V_B and lower the film. The complete servo system may be block diagramed as below, where it is noted to have two feedback loops; one for mechanical position detection and the one just described for error detection and correction.

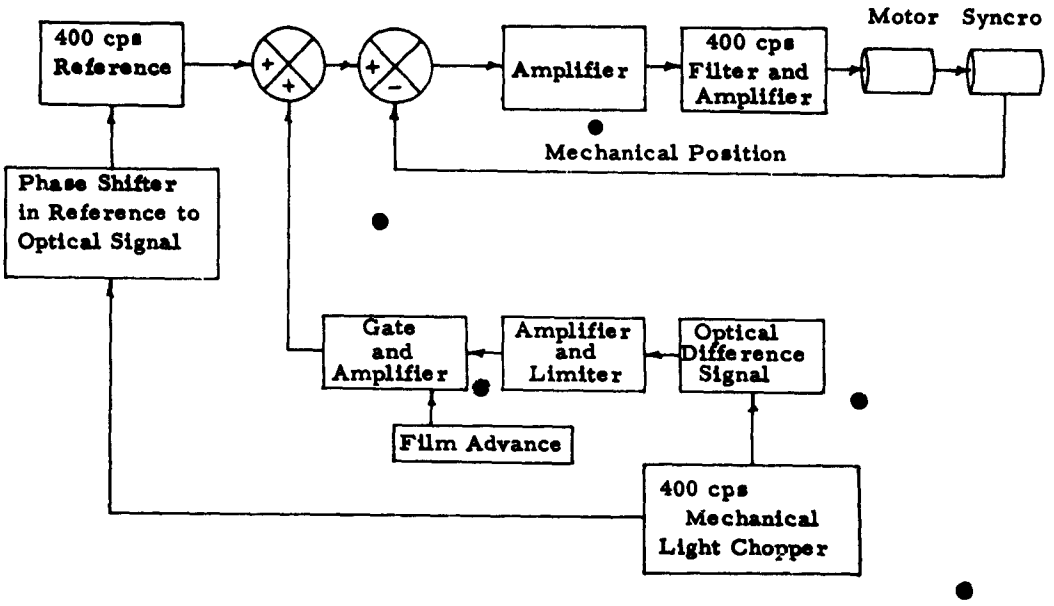
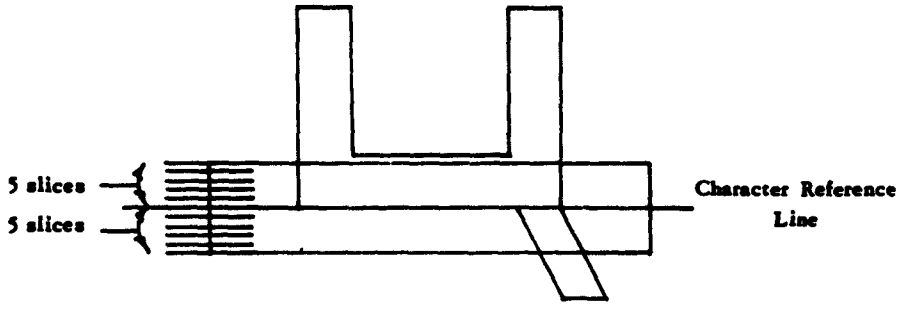


Figure 5. Servo System Block Diagram.

The gate in the feedback loop is used to inhibit the fine positioning signal and to advance the film to the next line.

The regular occurrence of misregistration below a base line of several characters has been noticed by Baird-Atomic and the masks shifted accordingly. This was taken into account in the character digitalization.

A sample of one line of text was chosen at random and the operation of the line follower simulated. The sampling mask was chosen as 0.01254 inches high when referenced back to the document which corresponds to 6 bits in the IBM 7090 simulation. The bottom edge of each character was divided into ten slices, each one bit wide, and these slice areas computed for each character in the sample line.



The action of the line follower was simulated by summing the respective slice areas for 14 consecutive character spaces and assuming that the area was evenly distributed in each slice.

Each slice (0.00209 inch on the document) was broken into 10 segments, each therefore about 0.2 thousands of an inch. It was found that the addition of a cyrillic letter such as P with the large descending bar lowers the average line as established by the line follower by one segment, or about 0.0002 inch at the document. The improbable occurrence of a string of 14 characters with descenders could cause the line follower to descend 0.0028 inch. The average base line may therefore be easily seen to remain within a ±1 bit (±0.00209 inch) tolerance. An exception to the above tolerance limits occurs at the start and finish of a line, as the line follower is using less than 14 character spaces to establish the average line.

This simulation has ignored the logarithmic response of the PMT in order to keep the analysis tractable. This logarithmic response increases the sensitivity of the servoing.

SIMULATION PROGRAM

The Baird-Atomic character recognition scheme uses the identity:

$$P - N = 2P - (P + N)$$

where:

P is the measure of match between the input character and the positive reference mask (1 for perfect match).

N is the measure of match between the input character and a negative reference mask (0 for perfect match).

(P + N) is proportional to the area of the character and is measured by a clear field of view aperature.

A perfect match then has a channel output of $P - N = 1 - 0 = 1$ or $2P - (P + N) = 2 - 1 = 1$ when normalized for that channel.

The following tabulation lists the Field-Of-View numbers, their width in bits (columns), and the reference characters associated with each mask. (See Table 1).

Input and output for the IBM 7090 simulation program are accomplished through the medium of magnetic tapes. Two input tapes are required, one consisting of digitalized reference masks and the other, digitalized input characters. For a given reference-input combination the input character is superimposed upon the reference mask at a number of space-time positions specified by control parameters. For each overlay, the area common to the input character and reference mask is compiled, as well as the area common to the input character (at that particular space-time position) and the fixed field mask, whose absolute spatial position is defined relative to the reference mask. A figure of match is then compiled and stored. When all specified superpositions have been processed, the complete data for this input-reference combination is recorded on an output tape (for future processing, if desired) and is simultaneously selectively edited and recorded on another output tape, which then constitutes the primary results of the computation. The data associated with the superposition yielding maximum match is stored.

Five modes of operation of the simulation are provided (and selected by control parameters) to allow for two objectives: (1) the specification of desired input-reference combinations; (2) the thorough investigation of the actual operation of the hardware. One may specify computation for a fixed set of space-time superpositions or operate under various and selectable degrees of discrete approximation to the continuous passage of input characters over reference and fixed field masks. When all specified input and reference combinations have been processed, the data associated with the maximum match for each combination is edited, sorted and tabulated on the output

TABLE I.
Mask Sizes and Associated Characters

Field-Of-View Aperture No.	Width	Reference Characters
1	13	78, 80, 82, 85
2	19	83, 84
3	25	75
4	29	79, 86
5	31	1, 46, 50
6	33	6, 48, 72
7	35	2, 3, 4, 7, 45, 60, 64, 76, 87, 88
8	37	5, 8, 9, 10, 43, 44, 52, 53, 54, 61, 66, 74
9	39	18, 47, 51, 58, 62
10	43	14, 27, 57, 59, 65
11	43	12, 13, 29, 39, 40, 42, 56, 63, 69
12	45	16, 55
13	47	21, 28, 32, 34
14	51	11, 22, 25, 30, 70
15	53	26, 31, 71, 73
16	53	20, 24, 49, 77
17	55	19, 33
18	59	15, 37, 67, 68
19	63	23, 38
20	69	
21	71	41, 89
22	73	17, 35, 36, 81

tape in two ways: (1) by order of reference character; and (2) by descending magnitude of the figure of match.

Two objectives were given prime consideration in the design of the program: (1) speed of computation. Approximately 230,000 double superpositions (input on reference and input on fixed field mask) are accomplished in twenty minutes. Twenty more minutes are required for output and editing of the resulting data. (2) flexibility. Assuming compatibility with the physical limitations of tape and storage, the program was designed to allow for the following possibilities. Input routines are easily alterable to accommodate any type or number of characters or masks. The algorithm which determines the area common to input and reference characters is easily alterable to accommodate any size of character matrix. In addition, this section may easily be expanded to include one of several schemes to simulate the effects of noise (vibration) on mask positioning. The computational algorithm is easily alterable to admit the determination of any prescribed index or measure of match. The editing portion of the program may be easily enlarged or may be eliminated completely, relegating this function to auxiliary program designed for less expensive machines.

AUXILIARY PROGRAMS

A library of auxiliary programs was developed to provide input for and service output of the simulation program. One program develops, from punched octal cards in a single pass, binary tapes constituting perfect input characters and reference masks, elogated and shifted reference masks (which constitute input tapes for the simulation), as well as a punch tape, which may be

used off-line to provide punched card decks corresponding to these output tapes. Other programs were developed to process selectively the intermediate binary data output of the simulation, preparing them for processing by existing large scale data sort, merge and editing programs.

DATA ARRANGEMENT

The printouts in Parts 1 thru 3 of the Data Printout Book* represent the character digitalization. Part 1 is the unaltered characters with each star representing an area 0.00209 inch square when referenced back to the original document. The reference line of each character falls on line 68 of the printouts, which is noted by a star. The width of each character is shown by the column listing and the area of each character is shown by the column listing and the area of each character is listed as the "Total No. of Bits in Grid".

Parts 2 and 3 represent the character masks with respectively a ±1 and ±2 bit vertical expansion. The character area change is shown and the vertical expansion is noted by the character numbering. For example, #051 is unaltered character #51; #151 is character #51 with a ±1 bit vertical expansion; and, #251 is character #51 with a ±2 bit vertical expansion.

Parts 4 thru 8 are the simulation runs, with the page headings as follows:

Vertical ( ) – This is the vertical position in bits of the input character base line relative to the reference character base line.

Page ( ) – Page number in ascending order for the data in each part.

The column headings are as follows, reading from right to left:

REF – reference character number
INP – input character number
DEL – delta change in raster from row to row of data (1⟶1 bit)
NORM – normalizing area of reference character
L – line number position of right hand column of input character on reference character for which each row of data is listed
MASK – bit count (representing area measure) of input character occurring in mask associated with reference character (P + N)
P – count of common bits between input and reference character (measure of common area)
UN MAT – the match value in bits 2P – (P + N)
MATCH – the match value normalized by the bit count (area) of the reference character

In order to simplify the data printout, only match values above 0.5 were printed. The maximum value for each reference-input combination was flagged by placing a star next to the reference character number in the row in which it occurs. When the crosscorrelation values are less than 0.5 for all positions, the maximum is printed as a single entry for that particular input-reference combination.

The last four pages of each printout of Parts 4 thru 8 contain the maximum match value for each input-reference combination ordered sequentially by reference character number and also by decreasing match value. These four summary sheets for each part have been included at the end of this report (Pages 26 thru 45).

The fold-out charts on Pages 12 thru 14 represent a tabulation from the summary sheets of Pages 26 thru 45. The definitions of the last four column headings are:

E > F Crosscorrelation of perfect on perfect at 0 vertical–greater than–autocorrelation of perfect on perfect at +1 vertical

E > J Crosscorrelation of perfect on perfect at 0 vertical–greater than–autocorrelation of perfect on perfect at +2 vertical

*Sample pages from the Data Printout Book have been included and are Page 22 for Parts 1 thru 3 and Pages 23 thru 45 for Parts 4 thru 8.

Reference Character		Input Character		Cross-Match	+1 Vertical Auto-Match	Input Character		Cross-Match	+2 Vertical Auto-Match	Input Character		Cross-Match	±1 Expanded Mask Input Character		Cross-Match	±2 Expanded Mask Input Character		Cross-Match	E F	E J	P I	S I
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S				
1	1	22	Л	0.76	0.87	22	Л	0.72	0.73	22	Л	0.66	22	Л	0.81	22	Л	0.85	x			
2	2	86	?	0.20	0.73	3	3	0.12	0.50	22	Л	0.11	86	?	0.33	9	9	0.43				
3	3	8	8	0.42	0.71	6	6	0.28	0.43	6	6	0.23	8	8	0.68	8	8	0.86				
4	4	1	1	0.61	0.78	1	1	0.57	0.57	1	1	0.51	1	1	0.64	19	И	0.66	x			
5	5	3	3	0.33	0.71	6	6	0.43	0.43	73	Ю	0.36	6	6	0.53	6	6					
6	6	10	0	0.44	0.72	73	Ю	0.40	0.44	73	Ю	0.29	10	0	0.65	5	5	0.76	x			
7	7	75	/	0.16	0.75	75	/	0.18	0.59	75	/	0.17	75	/	0.28	75	/	0.40				
8	8	3	3	0.57	0.77	3	3	0.58	0.54	3	3	0.47	3	3	0.67	3	3	0.70	x			
9	9	10	0	0.57	0.76	10	0	0.49	0.53	10	0	0.38	10	0	0.66	10	0	0.71	x			
10	0	9	9	0.55	0.82	6	6	0.52	0.65	6	6	0.40	9	9	0.68	9	9	0.75				
11	A	84	)	0.16	0.76	84	)	0.16	0.54	84	)	0.16	4	4	0.23	52	И	0.37				
12	Б	38	Ь1	0.70	0.79	38	Ь1	0.75	0.57	38	Ь1	0.62	13	В	0.80	13	В	0.86	x			
13	В	37	Ъ	0.65	0.77	18	З	0.58	0.55	38	Ь1	0.50	12	Б	0.82	12	Б	0.89	x			
14	Г	22	Л	0.68	0.82	19	И	0.65	0.63	29	Т	0.61	29	Т	0.82	29	Т	0.96	x			
15	Д	22	Л	0.57	0.79	36	Щ	0.51	0.57	36	Щ	0.40	36	Щ	0.65	36	Щ	0.72	x			
16	Е	35	Ш	0.53	0.72	35	Ш	0.48	0.43	35	Ш	0.40	13	В	0.69	13	В	0.78	x			
17	Ж	21	К	0.52	0.78	21	К	0.52	0.56	21	К	0.42	21	К	0.56	21	К	0.57				
18	З	13	В	0.42	0.73	28	С	0.31	0.46	25	О	0.32	13	В	0.64	13	В	0.72				
19	И	20	Й	0.72	0.83	24	Н	0.66	0.67	24	Н	0.54	24	Н	0.80	24	Н	0.83	x			
20	Й	19	И	0.71	0.77	19	И	0.60	0.54	19	И	0.47	19	И	0.86	19	И	0.92	x			
21	К	17	Ж	0.70	0.77	17	Ж	0.58	0.56	41	Ю	0.42	17	Ж	0.95	17	Ж	0.99	x			
22	Л	15	Д	0.51	0.80	15	Д	0.50	0.61	36	Щ	0.43	15	Д	0.71	15	Д	0.78				
23	М	30	У	0.25	0.84	30	У	0.27	0.68	30	У	0.24	30	У	0.35	30	У	0.40				
24	Н	33	Ц	0.71	0.83	33	Ц	0.61	0.66	33	Ц	0.50	33	Ц	0.82	33	Ц	0.83	x			
25	О	41	Ю	0.52	0.80	41	Ю	0.33	0.60	41	Ю	0.17	41	Ю	0.69	41	Ю	0.76				
26	П	33	Ц	0.64	0.82	24	Н	0.62	0.66	24	Н	0.50	33	Ц	0.79	33	Ц	0.82				
27	Р	14	Г	0.64	0.80	14	Г	0.62	0.61	14	Г	0.53	14	Г	0.68	29	Т	0.70	x			
28	С	41	Ю	0.50	0.74	25	О	0.49	0.49	25	О	0.50	41	Ю	0.59	25	О	0.74	x			
29	Т	14	Г	0.68	0.83	14	Г	0.58	0.67	14	Г	0.48	14	Г	0.70	14	Г	0.70	x			
30	У	25	О	0.11	0.78	25	О	0.09	0.56	84	)	0.09	25	О	0.18	23	М	0.26				

Reference Character		Input Character		Cross-Match	+1 Vertical Auto-Match	Input Character		Cross-Match	+2 Vertical Auto-Match	Input Character		Cross-Match	±1 Expanded Mask Input Character		Cross-Match	2±Expanded Mask Input Character		Cross-Match	E F	E J	P I	S I
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S				
31	Ь	1	1	0.35	0.77	1	1	0.32	0.54	1	1	0.30	1	1	0.37	1	1	0.39				
32	Х	21	К	0.27	0.75	25	0	0.21	0.50	25	0	0.18	21	К	0.41	17	Ж	0.52				
33	Ц	24	Н	0.69	0.85	24	Н	0.74	0.70	24	Н	0.63	24	Н	0.77	24	Н	0.77				
34	Ч	26	П	0.53	0.81	36	Щ	0.49	0.62	36	Щ	0.43	36	Щ	0.56	36	Щ	0.57				
35	Ш	36	Щ	0.61	0.84	36	Щ	0.54	0.68	36	Щ	0.40	36	Щ	0.70	36	Щ	0.72				
36	Щ	35	Ш	0.60	0.83	35	Ш	0.48	0.66	35	Ш	0.34	35	Ш	0.65	35	Ш	0.67				
37	Ъ	39	Ь	0.62	0.79	39	Ь	0.61	0.58	38	Ы	0.55	39	Ь	0.70	12	Б	0.75		x		
38	Ы	39	Ь	0.56	0.79	39	Ь	0.43	0.60	39	Ь	0.29	39	Ь	0.61	39	Ь	0.61				
39	Ь	38	Ы	0.85	0.77	38	Ы	0.85	0.54	38	Ы	0.64	38	Ы	1.02	38	Ы	1.05	x	x	x	x
40	Э	41	Ю	0.28	0.64	41	Ю	0.39	0.29	41	Ю	0.34	41	Ю	0.48	18	Э	0.59				
41	Ю	21	К	0.40	0.77	25	О	0.38	0.55	25	О	0.43	21	К	0.52	21	К	0.59				
42	Я	34	Ч	0.47	0.79	34	Ч	0.41	0.58	36	Щ	0.36	34	Ч	0.57	17	Ж	0.64				
43	а	50	з	0.51	0.73	50	з	0.50	0.46	50	з	0.38	50	а	0.65	50	з	0.71		x		
44	б	73	ю	0.56	0.74	73	ю	0.46	0.49	6	б	0.32	57	е	0.64	57	о	0.66		x		
45	в	69	ъ	0.51	0.66	69	ъ	0.59	0.32	71	Ь	0.43	69	ъ	0.75	67	ш	0.87		x		
46	г	74	я	0.62	0.76	67	ш	0.70	0.53	54	л	0.61	61	т	0.84	61	т	0.88		x		
47	д	54	л	0.59	0.72	54	л	0.59	0.44	54	л	0.43	54	л	0.78	54	л	0.80		x		
48	е	60	с	0.66	0.68	60	с	0.51	0.37	60	с	0.30	60	с	0.74	60	с	0.76		x		
49	ж	53	к	0.56	0.72	53	к	0.45	0.47	53	к	0.30	53	к	0.56	53	к	0.56		x		
50	з	72	в	0.48	0.63	72	в	0.27	0.27	66	ч	0.14	72	в	0.72	43	в	0.87		x		
51	и	56	и	0.83	0.77	52	й	0.69	0.57	58	т	0.52	56	и	0.89	56	и	0.90	x	x		
52	й	51	и	0.62	0.74	51	и	0.45	0.48	56	и	0.29	51	и	0.78	51	и	0.80		x		
53	к	49	ж	0.76	0.70	49	ж	0.61	0.42	49	ж	0.34	49	ж	1.00	49	ж	1.01	x	x	x	x
54	л	47	д	0.60	0.78	47	д	0.47	0.56	67	ш	0.32	47	д	0.69	47	д	0.73		x		
55	м	51	и	0.36	0.80	51	и	0.29	0.61	66	ч	0.24	51	и	0.43	51	и	0.50				
56	н	68	щ	0.83	0.76	58	т	0.75	0.52	58	т	0.58	58	т	0.93	58	т	0.93	x	x	x	x
57	о	73	ю	0.67	0.74	73	ю	0.68	0.49	73	ю	0.53	73	ю	0.75	73	ю	0.78		x		
58	п	68	щ	0.80	0.79	67	ш	0.68	0.60	67	ш	0.53	65	ц	0.84	65	ц	0.86	x	x		
59	р	46	г	0.38	0.77	46	г	0.37	0.56	46	г	0.31	57	о	0.49	58	т	0.55				
60	с	48	е	0.57	0.70	48	е	0.50	0.40	48	е	0.23	48	е	0.80	48	е	0.83		x		

Reference Character		Input Character		Cross-Match	+1 Vertical Auto-Match	Input Character		Cross-Match	+2 Vertical Auto-Match	Input Character		Cross-Match	±1 Expanded Mask Input Character		Cross-Match	±2 Expanded Mask Input Character		Cross-Match	E F	E J	P I	S 1
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S				
61	т	46	г	0.57	0.77	54	л	0.49	0.54	54	л	0.33	46	г	0.65	46	г	0.66		x		
62	у	46	г	0.07	0.70	46	г	0.04	0.42	46	г	0.02	54	л	0.11	54	л	0.20				
63	ф	67	ш	0.40	0.80	67	ш	0.35	0.60	67	ш	0.27	67	ш	0.52	67	ш	0.60				
64	х	60	с	0.23	0.62	53	к	0.24	0.26	60	с	0.15	53	к	0.51	49	ж	0.68				
65	ц	68	щ	0.88	0.80	68	щ	0.85	0.61	67	ш	0.68	68	щ	0.90	68	щ	0.90	x	x		
66	ч	67	ш	0.51	0.76	67	ш	0.43	0.54	67	ш	0.34	58	т	0.62	58	т	0.67				
67	щ	68	щ	0.82	0.79	68	щ	0.63	0.59	68	щ	0.43	68	щ	0.85	68	щ	0.86	x	x		
68	ш	67	ш	0.82	0.79	67	ш	0.73	0.58	67	ш	0.55	67	ш	0.91	67	ш	0.92	x	x		
69	ъ	71	ь	0.81	0.70	71	ь	0.67	0.41	71	ь	0.43	71	ь	0.92	70	ы	0.93	x	x		
70	ы	71	ь	0.58	0.76	71	ь	0.45	0.53	71	ь	0.29	71	ь	0.60	71	ь	0.60		x		
71	ь	69	ъ	0.79	0.72	69	ъ	0.54	0.46	69	ъ	0.27	69	ъ	0.83	69	ъ	0.83	x	x		
72	э	50	з	0.52	0.64	50	з	0.43	0.29	50	з	0.24	50	з	0.70	50	з	0.83		x		
73	ю	57	о	0.45	0.74	53	к	0.39	0.48	53	к	0.29	57	о	0.60	57	о	0.66				
74	я	56	и	0.50	0.72	56	и	0.50	0.43	51	и	0.38	56	и	0.71	56	и	0.80		x		
75	/	37	ъ	0.10	0.84	37	ъ	0.09	0.72	37	ъ	0.08	11	А	0.19	11	А	0.28				
76	-	89	—	0.31	0.58	89	—	0.29	0.17	89	—	-0.13	89	—	0.34	89	—	0.34		x		
77	%	75	/	0.29	0.80	75	/	0.31	0.59	75	/	0.30	75	/	0.31	75	/	0.32				
78	:	79	.	0.33	0.66	82	;	0.41	0.33	82	;	0.45	82	;	0.56	82	;	0.88		x		
79	.	78	:	-0.11	0.72	78	:	-0.38	0.45	89	—	-0.63	78	:	-0.02	80	,	0.18				
80	,	15	Д	0.40	0.75	15	Д	0.45	0.53	79	.	0.52	15	Д	0.48	15	Д	0.54				
81	№	23	М	0.12	0.80	85	!	0.08	0.61	85	!	0.07	23	М	0.29	23	М	0.41				
82	;	78	:	0.40	0.72	79	.	0.32	0.43	79	.	0.28	78	:	0.57	78	:	0.66				
83	(	70	ы	0.39	0.85	70	ы	0.37	0.70	70	ы	0.36	54	л	0.42	54	л	0.45				
84	)	73	ю	0.38	0.86	73	ю	0.38	0.71	73	ю	0.38	51	и	0.40	77	%	0.45				
85	!	1	1	0.46	0.86	1	1	0.40	0.73	34	Ч	0.40	1	1	0.63	38	Ы	0.77				
86	?	27	Р	0.22	0.73	27	Р	0.22	0.46	27	Р	0.11	27	Р	0.45	27	Р	0.55				
87	«	60	с	0.07	0.66	69	ъ	0.06	0.34	69	ъ	0.06	60	с	0.24	60	с	0.41				
88	»	73	:	0.09	0.66	46	г	0.07	0.33	46	г	0.07	73	ю	0.24	49	ж	0.42				
89	—	76	-	0.19	0.49	76	-	0.07	-0.01	74	я	-0.03	76	-	0.30	76	-	0.30				
																			10	46	2	2

P > 1 Crosscorrelation of perfect on ±1 vertically expanded mask at 0 vertical–greater than–one

S > 1 Crosscorrelation of perfect on ±2 vertically expanded mask at 0 vertical–greater than–one

The sensitivity of the autocorrelation to vertical alignment was anticipated by Baird-Atomic and a possible solution proposed. The proposed solution was to expand the masks in the vertical direction so that the input character would fall totally within the mask even if misregistered an amount equal to or less than the mask expansion. The vertical mask expansion gives a proportional decrease in sensitivity to vertical position, but also gives rise to an increase in the crosscorrelation maximum (See Figure 7).

Figures 6 and 7 below indicate the changes in the autocorrelation and crosscorrelation values due to vertical misregistration and vertical mask slurring.

Figure 6 shows that the median autocorrelation drops from a normalized maximum of 1.0 when correctly positioned to a value of 0.76 when displaced vertically by one bit (0.00209 inch at the document). This autocorrelation median drops to 0.56 for a two bit vertical shift.

Figure 7 shows the range of crosscorrelation maximums for perfect masking and for vertically slurred masks. The increased vertical insensitivity obtained by vertically expanding (slurring) the mask is offset by an increase in the crosscorrelation values, that is, a loss in discrimination.

The match values obtained for a given reference character are normalized by the area of that reference character. This sets 1.0 as a perfect match and references all other match values to this. The actual channel voltage signals are dependent on the light source, system transmission, PMT gain, noise levels, etc. The relative channel signals may be calculated on the basis of the reference character area. For example, the smallest character is a period, #79 (.) and the largest is a capitol letter, #17 (Ж). Their respective areas are 65 bits and 1252 bits. Therefore, although both perfect match values are 1.0, the voltage levels in channel #17 is 1252/65 = 19.3 times that in channel #79.

ERROR RATES

An error rate table was constructed by using the autocorrelation and crosscorrelation tabulation for perfect characters with misalignment and on expanded (slurred) masks.

The error rate is given in Table II and is the number of *missed* characters per 1000 random input characters. The system noise is completely ignored and an error is defined only when the crosscorrelation becomes equal to or greater than the autocorrelation in a given channel. The area dropout or addition per cent is a direct measure of the reduced or increased character area as seen by the character matrix.

The error rate has been tabulated taking into account the character frequencies as given in the NYU study. (Reference, Page 1.) The tabulation of the upper and lower case character frequencies has been included and is shown on Page 19.

The electronic controls for the character channels generate an inhibit pulse blocking all channels for the remainder of the character space after one character channel has triggered. This technique is helpful when crosscorrelation peaks are close to or greater than autocorrelation peak values but occur (in time) after the autocorrelation peak has triggered the correct channel. When the competitive crosscorrelation peak would ordinarily occur before the autocorrelation peak, a similar blanking effect is obtained by shifting the relative positions of the reference apertures so as to change the order in which the peaks occur. This blanking possibility was not taken into account in computing the error rates in Table II.

When this blanking is incorporated along with a ±0.004 inch expanded mask, as much as 7% of the area of a character can be deleted with a vertical misalignment of as much as ±0.004 inch before the first error occurs.

It is possible to calculate another error rate due to the Gaussian nature of the photomultiplier tube (PMT) output. This was done for channel #51 representing the cyrillic letter И. The shot

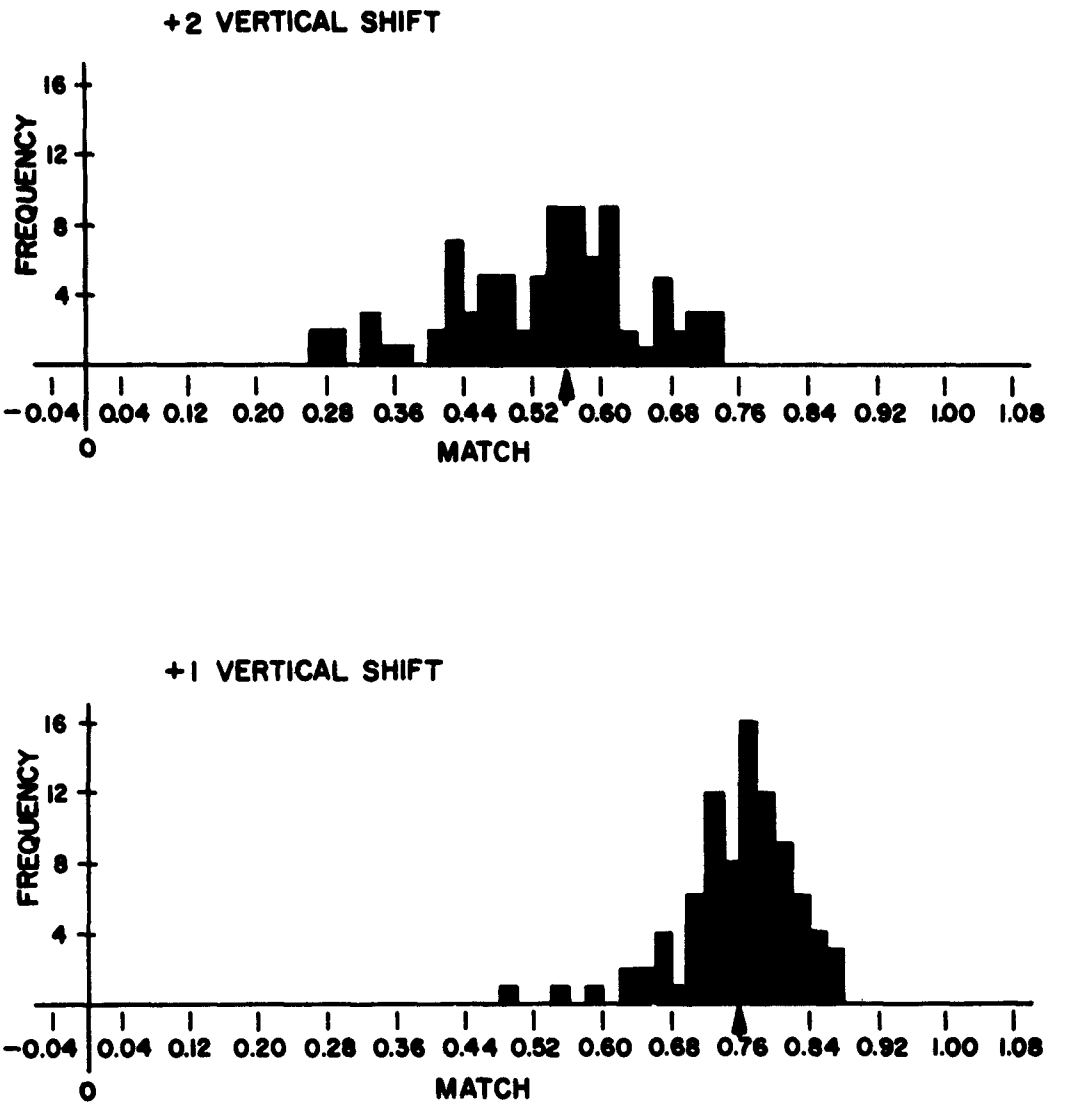


Figure 6. Auto-Correlation Variations.

noise of the photomultiplier tubes was assumed to have a Gaussian distribution with a standard deviation in photo-electrons equal to the square root of the total number of photo-electrons occurring per sample time.* The recognition technique is such that the signal from the positive mask

*Smullin, L. D. and Haus, H. A. (eds.): "Noise in Election Devices," Page 58, John Wiley and Sons, Inc., New York, 1959.

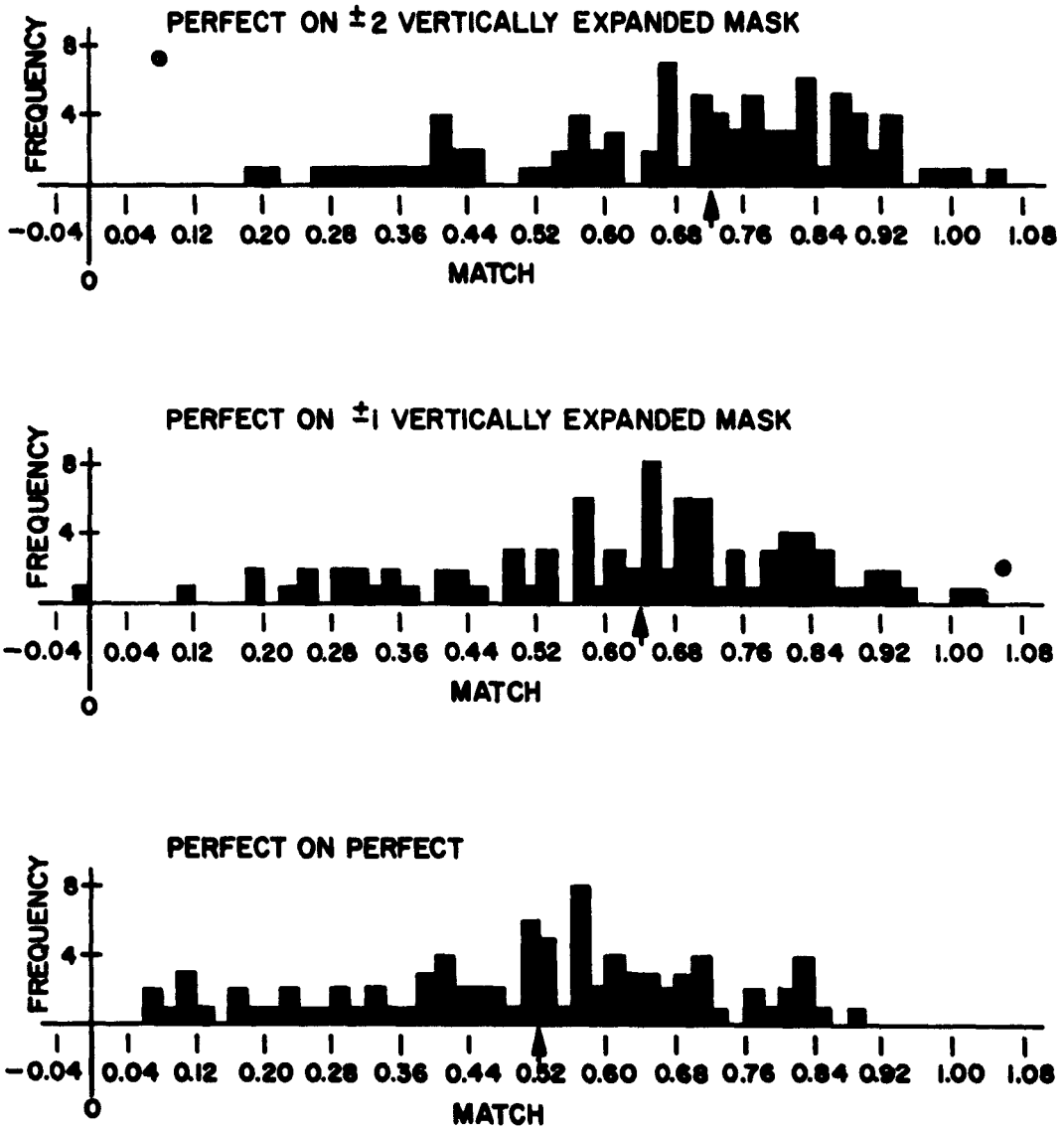


Figure 7. Cross-Correlation Variations (0 Vertical Displacement).

PMT is doubled (2P) and summed with the inverted signal from the field of view (FOV) aperature PMT [– (P + N)]. The standard deviation of the total signal is then equal to

$$\sigma = \sqrt{(2\,\sigma_P)^2 + (\sigma_{(P+N)})^2}$$

where

σ_P standard deviation of mask PMT signal

$\sigma_{(P+N)}$ standard deviation of FOV PMT signal

The threshold level for firing the channel indicator was chosen for minimum error at a point between the maximum crosscorrelation (0.89) and the autocorrelation (1.0) signal where the standard deviation of the two signals were equal (0.94). The highest crosscorrelation (0.89) was for the perfect character #56 (H) on the ±1 bit vertically expanded (slurred) mask of reference character #51.

TABLE II.
Error Rates (Lower Bound)

Area Dropout or Addition in Per Cent	Perfect on Perfect 0 Vertical		Perfect on Perfect ±1 Vertical		Perfect on ±1 Mask 0 Vertical		Perfect on ±2 Mask 0 Vertical	
	Errors	Char.	Errors	Char.	Errors	Char.	Errors	Char.
0	0	0	238	10	33	2	33	2
1	0	0	etc.		33	2	34	3
2	0	0			33	2	34	3
3	0	0			33	2	34	3
4	0	0			33	2	34	4
5	0	0			34	3	34	4
6	0	0			34	3	34	4
7	0	0			100	4	100	5
8	0	0			100	4	104	7
9	0	0			104	5	104	7
10	0	0			107	6	195	9
11	0	0			195	7	etc.	
12	3	1			etc.			
13	3	1						
14	3	1						
15	3	2						
16	3	2						
17	157	4						
18	169	6						
	etc.							

The numbers in the character (char.) column refer to the total number of characters contributing to the error rate.

Error rates above 15% (150 per 1000) are not extensively tabulated.

The error rate listed is for 1000 random input characters.

The error rate is divided into two parts:

(1) the errors which occur when character #51 appears in its own channel and is not recognized, and

(2) when some other character (as #56 above) appears in channel #51 and is recognized incorrectly as character #51.

TABLE III.
Character Frequencies

Character No. (Upper Case)	Frequency in Per Cent	Character No. (Lower Case)	Frequency in Per Cent
11	0.09	43	7.21
12	0.05	44	1.55
13	0.18	45	4.56
14	0.03	46	1.31
15	0.03	47	2.72
16	0.04	48	9.55
17	0.01	49	0.80
18	0.04	50	1.66
19	0.08	51	8.77
20	0.01	52	0.92
21	0.09	53	3.30
22	0.04	54	4.50
23	0.09	55	3.21
24	0.20	56	6.59
25	0.09	57	10.15
26	0.11	58	2.37
27	0.07	59	5.21
28	0.26	60	5.31
29	0.09	61	6.56
30	0.03	62	2.50
31	0.02	63	0.21
32	0.02	64	1.02
33	0.00	65	0.31
34	0.05	66	1.31
35	0.01	67	0.80
36	0.00	68	0.40
37	0.00	69	0.01
38	0.00	70	2.42
39	0.00	71	1.18
40	0.07	72	0.27
41	0.00	73	0.48
42	0.01	74	1.06
Frequency of Upper Case	1.18%	Frequency of Lower Case	98.82%

The first type of error – correct character not recognized – is represented by the area of the autocorrelation probability curve shown in Figure 8 which is below the threshold value of 0.94. The second type of error – wrong character recognized – is represented by the area of the cross-correlation probability curves shown in Figure 7 which exceed the threshold value of 0.94. The error rate contributions are shown below for channel #51 (M).

23.4 microseconds sample time

$6.7 \times 10^5 \frac{\text{photo-electrons}}{\text{bit}}$/sample time

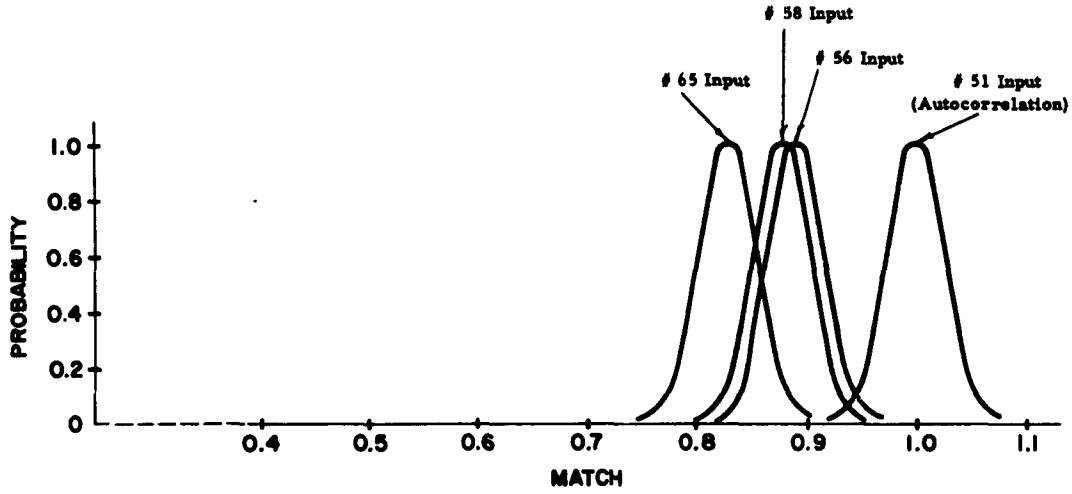


Figure 8. Match Values for Channel #51.

The error rate per 1000 random characters for each input is obtained by multiplying the character frequency of occurrence (See Page 18) by the error rate per 1000 repeats of the same input character.

The total error rate contributed by this channel is therefore 2.61^+ errors per 1000 random input characters.

This character channel (#51) has the highest error rate of all characters, but it is easily seen that this order of magnitude error rate per channel is entirely excessive when there are 89 independent channels contributing.

This calculation was based on the light levels obtained with the source now mounted on the machine (30 ampere tungsten ribbon filament) and on a sample time of 23.4 microseconds as an indicated minimum from the IBM 7090 simulation. The light level at the PMT's was therefore 15.7 photo-electrons/bit/ sample time where a bit again refers to square area 0.00209 inch on a side referenced back to the original document.

This calculation was only based on the effects of shot noise in the PMT's and ignored Johnson Noise, Amplifier Noise, Vibration Noise, etc. The system PMT noise level is now fairly high but a simple calculation reveals that a doubling* of the light level received at the PMT's decreases the total error rate for Channel #51 by a factor of 8.4.

*An increase of the light level received at the PMT's may be accomplished by coating the main lens as to their specifications and by modifying the light source.

TABLE IV.
Shot Noise Error Rates For Channel #51

Input Character		Frequency in Per Cent	Correct Character Not Recognized		Wrong Character Recognized	
#	Symbol		Errors per 1000 Repeats of Input	Errors per 1000 Random Characters	Errors per 1000 Repeats of Input	Errors per 1000 Random Characters
51	И	8.77	15.4	1.35	–	
56	Н	6.59	–		15.4	1.07
58	П	2.37	–		8.2	0.19
65	Ц	0.31	–		0^+	0^+
			Sub Totals	1.35		1.26^+

CONCLUSIONS

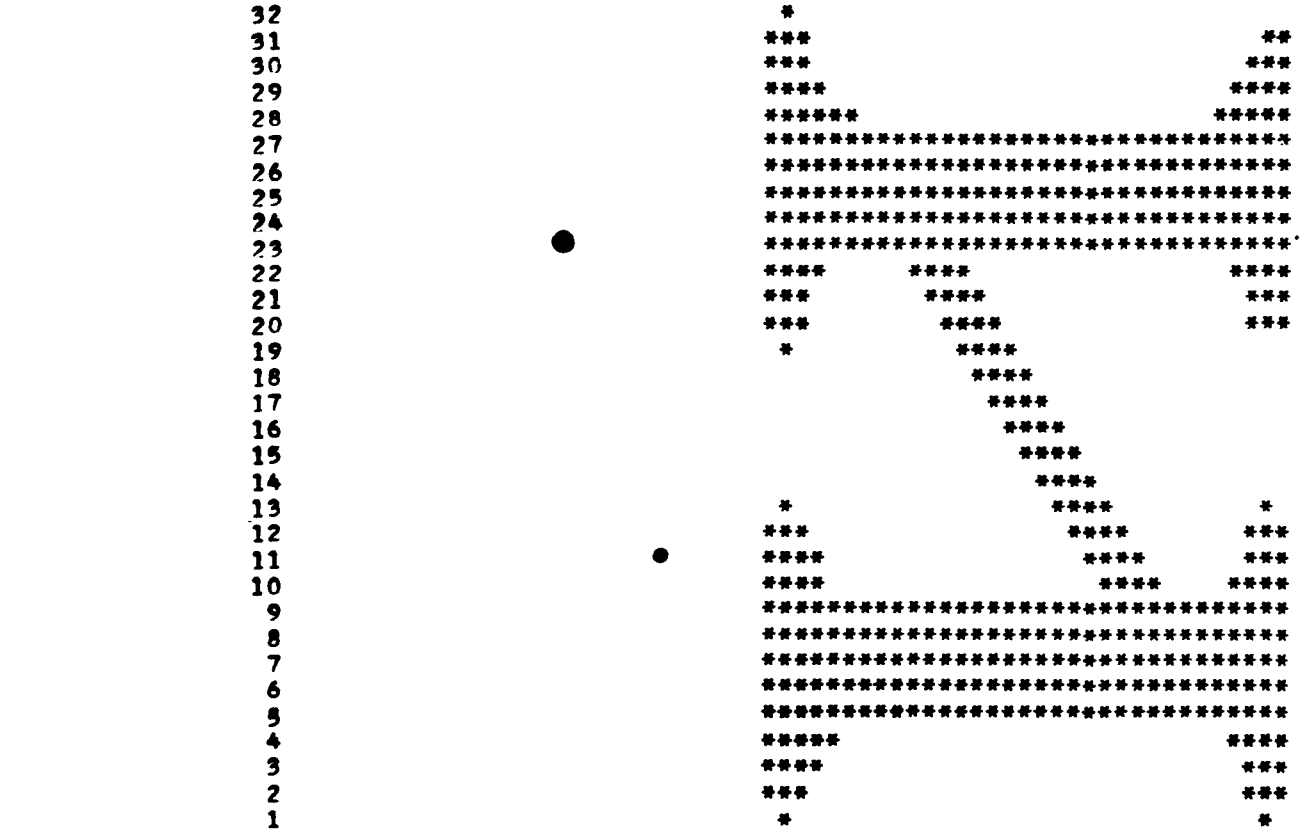
The IBM 7090 simulation of an idealized electro-optical system indicates that for very high quality characters and with very close tolerances on text registration, the basic masking technique yields adequate discrimination between characters. In addition, an analysis of the line following technique indicates the basic approach will position excellent quality text to within a ±.002 inch vertical displacement referred to original text. This variation is the result of the random occurrence of input characters which contain descenders.

The tolerance of the masking technique to vertical misalignment can be improved with the vertical expansion (slurring) of the mask character as proposed by Baird-Atomic. However, as the amount of vertical slurring is increased, the discrimination between characters decreases and becomes more sensitive to characters malformed by area loss or addition.

For example, using a reasonably slurred mask, (±0.004 inch referred to original document) character area losses or additions in excess of 7% will seriously affect the reading reliability, even when the input characters are registered vertically within ±0.004 inch of the correct position.

The computer simulation undertaken under this task, although very comprehensive, is not conclusive for the following reasons. First, it dealt with only a single type font, and does not necessarily illustrate the typical character discriminations resulting with other type fonts. Second, there is no known study of the quality of Russian technical text which will relate the real life input from technical journals of interest to the printing quality constraints shown necessary by the simulation. And thirdly, it has not been established that it is technologically feasible to construct a practical system in which parameters such as electrical noise, optical resolution, and mechanical vibrations can be specified and held within adequate tolerances to obtain character discrimination necessary in a useful system. Feasibility of such an effort can only be determined by a comprehensive mechanical, electrical, and optical analysis of any proposed system, probably involving additional digital simulation.

N 051 123456789 123456789 123456789 123456789 123456789 123456789 123456789 12



TOTAL NO. OF BITS IN GRID 481

SIMULATION DATA

MATCH	UNMAT	P	VERTICAL MASK	0 L	NORM	DEL	PAGE INP	106 REF
0.0977	47	196	345	32	481	1	1	51*
-0.1040	-50	250	550	30	481	1	2	51*
-0.0936	-45	0	45	61	481	1	3	51*
0.0021	1	209	417	18	481	1	4	51*
-0.0665	-32	113	258	11	481	1	5	51*
-0.0042	-2	131	264	50	481	1	6	51*
-0.0582	-28	0	28	61	481	1	7	51*
-0.1518	-73	0	73	61	481	1	8	51*
-0.0852	-41	140	321	11	481	1	9	51*
0.0249	12	145	278	52	481	1	10	51*
-0.0333	-16	0	16	77	481	1	11	51*
-0.0561	-27	0	27	70	481	1	12	51*
-0.0457	-22	0	22	72	481	1	13	51*
-0.0270	-13	203	419	52	481	1	14	51*
-0.0665	-32	0	32	84	481	1	15	51*
-0.0291	-14	195	404	57	481	1	16	51*
-0.0541	-26	0	26	101	481	1	17	51*
-0.1455	-70	65	200	58	481	1	18	51*
-0.0187	-9	284	577	48	481	1	19	51*
-0.0457	-22	192	406	15	481	1	20	51*
-0.0104	-5	195	395	61	481	1	21	51*
0.0478	23	195	367	16	481	1	22	51*
-0.0312	-15	0	15	92	481	1	23	51*
-0.0665	-32	0	32	81	481	1	24	51*
-0.1414	-68	117	302	67	481	1	25	51*
0.0083	4	197	390	63	481	1	26	51*
-0.0478	-23	0	23	71	481	1	27	51*
-0.0852	-41	133	307	62	481	1	28	51*
-0.0748	-36	0	36	72	481	1	29	51*
-0.0270	-13	0	13	77	481	1	30	51*
-0.0042	-2	102	206	11	481	1	31	51*
-0.0686	-33	0	33	74	481	1	32	51*
-0.0686	-33	0	33	85	481	1	33	51*
0.0000	0	195	390	15	481	1	34	51*
0.0166	8	195	382	15	481	1	35	51*
-0.0208	-10	197	404	84	481	1	36	51*
0.0582	28	111	194	11	481	1	37	51*
0.0665	32	305	578	34	481	1	38	51*
0.0915	44	113	182	11	481	1	39	51*
-0.0270	-13	116	245	9	481	1	40	51*
0.0125	6	195	384	82	481	1	41	51*
-0.0166	-8	192	392	14	481	1	42	51*
0.4241	204	313	422	31	481	1	43	51*
0.0603	29	160	291	51	481	1	44	51*
0.4615	222	307	392	29	481	1	45	51*
0.3680	177	228	279	26	481	1	46	51*
0.3139	151	207	263	16	481	1	47	51*
0.2328	112	250	388	29	481	1	48	51*
0.4532	218	381	544	50	481	1	49	51*
0.2682	129	228	327	29	481	1	50	51*
0.6923	333	407	481	31	481	1	51	51
1.0000	481	481	481	32				
0.6923	333	407	481	33				
1.0000	481	481	481	32				*

MATCH	UNMAT	P	VERTICAL MASK	O L	NORM	DEL	PAGE INP	107 REF
0.5322	256	422	588	31	481	1	52	51
0.5322	256	422	588	31				*
0.5114	246	336	426	32	481	1	53	51
0.5114	246	336	426	32				*
0.3617	174	210	246	13	481	1	54	51*
0.2952	142	207	272	14	481	1	55	51*
0.6091	293	377	461	30	481	1	56	51
0.8254	397	429	461	31				
0.6341	305	383	461	32				
0.8254	397	429	461	31				*
0.1580	76	134	192	50	481	1	57	51*
0.5135	247	370	493	31	481	1	58	51
0.7256	349	421	493	32				
0.5343	257	375	493	33				
0.7256	349	421	493	32				*
0.1913	92	284	476	30	481	1	59	51*
0.2121	102	202	302	29	481	1	60	51*
0.2911	140	215	290	39	481	1	61	51*
-0.0166	-8	62	132	12	481	1	62	51*
0.1788	86	139	192	62	481	1	63	51*
0.2141	103	226	349	31	481	1	64	51*
0.6570	316	425	534	35	481	1	65	51
0.6570	316	425	534	35				*
0.5260	253	325	397	30	481	1	66	51
0.5593	269	333	397	31				
0.5593	269	333	397	31				*
0.6528	314	399	484	31	481	1	67	51
0.6778	326	407	488	32				
0.5239	252	370	488	48				
0.7464	359	421	483	49				
0.5800	279	379	479	50				
0.7464	359	421	483	49				*
0.7006	337	420	503	35	481	1	68	51
0.5301	255	379	503	36				
0.5759	277	371	465	52				
0.7900	380	421	462	53				
0.5884	283	371	459	54				
0.7900	380	421	462	53				*
0.4407	212	288	364	28	481	1	69	51*
0.3222	155	211	267	60	481	1	70	51*
0.4823	232	297	362	28	481	1	71	51*
0.1767	85	218	351	28	481	1	72	51*
0.3867	186	301	416	46	481	1	73	51*
0.5489	264	343	422	31	481	1	74	51
0.5489	264	343	422	31				*
-0.0644	-31	0	31	51	481	1	75	51*
0.0229	11	44	77	19	481	1	76	51*
-0.0499	-24	69	162	9	481	1	77	51*
0.1268	61	84	107	29	481	1	78	51*
0.0852	41	53	65	29	481	1	79	51*
-0.0416	-20	47	114	30	481	1	80	51*
0.0832	40	100	160	9	481	1	81	51*
0.1081	52	100	148	30	481	1	82	51*
0.0707	34	172	310	36	481	1	83	51*

MATCH	UNMAT	P	VERTICAL MASK	0 L	NORM	DEL	PAGE INP	108 REF
0.0208	10	176	342	11	481	1	84	51*
0.0312	15	125	235	29	481	1	85	51*
-0.0561	-27	0	27	54	481	1	86	51*
-0.0208	-10	159	328	30	481	1	87	51*
-0.0270	-13	170	353	31	481	1	88	51*
-0.0270	-13	20	53	10	481	1	89	51*

TABLE OF MAXIMA. VERTICAL 0

REF	INP	NORM	LINE	MASK	P	UNMAT	MATCH
1	22	345	18	383	322	261	0.7565
2	86	550	29	321	215	109	0.1982
3	8	511	30	696	455	214	0.4188
4	1	490	28	345	321	297	0.6061
5	3	509	30	511	340	169	0.3320
6	10	499	30	566	393	220	0.4409
7	75	384	25	248	154	60	0.1562
8	3	696	30	511	455	399	0.5733
9	10	595	30	566	452	338	0.5681
10	9	566	31	595	452	309	0.5459
11	84	665	35	346	226	106	0.1594
12	38	813	59	646	609	572	0.7036
13	37	831	40	727	635	543	0.6534
14	22	510	18	373	360	347	0.6804
15	22	828	49	682	575	468	0.5652
16	35	661	17	382	366	350	0.5295
17	21	1252	71	718	683	648	0.5176
18	13	646	35	809	541	273	0.4226
19	20	974	50	912	809	706	0.7248
20	19	912	49	974	809	644	0.7061
21	17	718	44	864	683	502	0.6992
22	15	682	53	805	575	345	0.5059
23	30	1037	50	680	472	264	0.2546
24	33	994	54	1009	855	701	0.7052
25	41	788	45	626	517	408	0.5178
26	33	812	54	994	757	520	0.6404
27	14	730	36	510	489	468	0.6411
28	41	587	46	595	443	291	0.4957
29	14	642	48	467	451	435	0.6776
30	25	680	20	399	237	75	0.1103
31	1	860	33	345	323	301	0.3500
32	21	758	45	716	462	208	0.2744
33	24	1039	50	994	855	716	0.6891
34	26	662	75	382	365	348	0.5257
35	36	1232	70	1219	981	749	0.6080
36	35	1219	66	1232	981	730	0.6018
37	39	821	53	605	558	511	0.6224
38	39	1000	39	605	580	555	0.5550
39	38	605	59	646	580	514	0.8496
40	41	560	40	556	355	154	0.2750
41	21	1007	45	718	560	402	0.3992
42	34	786	41	656	512	368	0.4682
43	50	422	25	327	272	217	0.5142
44	73	585	31	356	341	326	0.5573
45	69	392	29	364	282	200	0.5102
46	74	279	19	230	202	174	0.6237
47	54	413	32	420	331	242	0.5860
48	60	388	26	302	280	258	0.6649
49	53	755	52	426	423	420	0.5563
50	72	327	26	351	254	157	0.4801
51	56	481	31	461	429	397	0.8254
52	51	588	32	481	422	363	0.6173
53	49	426	32	522	423	324	0.7606
54	47	420	36	471	351	251	0.5976
55	51	588	40	481	345	209	0.3554

TABLE OF MAXIMA. VERTICAL

REF	INP	NORM	LINE	MASK	P	UNMAT	MATCH
56	68	461	53	471	426	381	0.8265
57	73	390	30	383	322	261	0.6692
58	68	493	54	462	429	396	0.8032
59	46	476	26	279	231	183	0.3845
60	48	302	27	388	280	172	0.5695
61	46	316	24	278	229	180	0.5696
62	44	364	11	72	48	24	0.0659
63	67	778	45	677	493	309	0.3972
64	60	349	42	219	150	81	0.2321
65	68	594	46	506	488	470	0.8801
66	67	397	31	484	344	204	0.5139
67	68	707	53	720	649	578	0.8175
68	67	720	49	707	649	591	0.8208
69	71	395	37	362	340	318	0.8051
70	71	605	28	362	346	330	0.5785
71	69	362	28	395	340	285	0.7873
72	50	351	26	327	254	181	0.5157
73	57	569	45	390	322	254	0.4464
74	56	422	31	461	337	213	0.5047
75	37	248	66	79	52	25	0.1008
76	89	77	65	102	63	24	0.3117
77	75	782	34	248	238	228	0.2916
78	79	107	9	65	50	35	0.3271
79	78	65	9	107	50	-7	-0.1077
80	15	114	56	66	56	46	0.4095
81	23	1084	64	1037	584	131	0.1208
82	78	148	9	107	83	59	0.3986
83	70	316	10	208	165	122	0.3861
84	79	346	51	213	172	131	0.3786
85	1	255	12	325	216	107	0.4553
86	27	321	23	327	198	69	0.2150
87	60	328	42	206	115	24	0.0792
88	79	359	19	181	106	31	0.0878
89	76	259	17	77	63	49	0.1892

TABLE OF MAXIMA. VERTICAL 0 PAGE 1

REF	INP	NORM	LINE	MASK	P	UNMAT	MATCH
65	68	534	36	506	488	470	0.8801
39	38	605	59	646	580	514	0.8496
56	68	461	53	471	426	381	0.8265
51	56	481	31	461	429	397	0.8254
68	67	720	49	707	649	591	0.8208
67	68	707	53	720	649	578	0.8175
69	71	395	37	362	340	318	0.8051
58	68	493	54	462	429	396	0.8092
71	69	362	28	395	340	285	0.7879
53	49	426	32	522	423	324	0.7606
1	22	345	18	383	322	261	0.7565
19	20	974	50	912	809	706	0.7248
20	19	912	49	974	809	644	0.7061
24	33	994	54	1009	855	701	0.7052
12	38	813	59	646	609	572	0.7036
21	17	718	44	864	683	502	0.6992
33	24	1039	50	994	855	716	0.6891
14	22	510	18	373	360	347	0.6804
29	14	642	48	467	451	435	0.6776
57	73	390	30	383	322	261	0.6692
48	60	388	26	302	280	258	0.6649
13	37	831	40	727	635	543	0.6534
27	14	730	36	510	489	468	0.6411
26	33	812	54	994	757	520	0.6404
46	74	279	19	290	202	174	0.6237
37	39	821	53	605	558	511	0.6224
52	51	588	32	481	422	363	0.6179
35	36	1232	70	1219	981	749	0.6080
4	1	490	28	345	321	297	0.6061
36	35	1219	66	1232	981	730	0.6018
54	47	420	36	411	331	251	0.5976
47	54	413	32	420	331	242	0.5860
70	71	605	28	362	356	350	0.5785
8	3	696	30	511	455	399	0.5733
61	46	316	34	278	229	180	0.5696
60	48	302	27	388	280	172	0.5695
9	10	595	30	566	452	338	0.5681
15	22	828	49	682	575	468	0.5652
44	73	585	31	356	341	326	0.5573
49	53	755	52	426	423	420	0.5563
38	39	1000	39	605	580	555	0.5550
10	9	566	31	595	452	309	0.5459
16	35	661	17	382	366	350	0.5295
34	26	662	75	382	365	348	0.5257
25	41	788	45	626	517	408	0.5178
17	21	1292	71	718	683	648	0.5176
72	50	351	26	327	234	181	0.5157
43	50	422	25	327	272	217	0.5142
66	67	397	31	484	344	204	0.5139
45	69	392	29	364	282	200	0.5102
22	15	682	53	805	575	345	0.5059
74	56	422	31	461	337	213	0.5047
28	41	587	46	595	443	291	0.4957
50	72	327	26	351	234	157	0.4801
42	34	786	41	656	512	368	0.4682

TABLE OF MAXIMA. VERTICAL 0 PAGE 2

REF	INP	NORM	LINE	MASK	P	UNMAT	MATCH
85	1	235	12	325	216	107	0.4553
73	57	569	45	390	322	254	0.4464
6	10	499	30	566	393	220	0.4409
18	13	646	35	809	541	273	0.4226
3	8	511	30	696	455	214	0.4188
80	15	114	56	66	56	46	0.4035
41	21	1007	45	718	560	402	0.3992
82	78	148	9	107	83	59	0.3986
63	67	778	45	677	493	309	0.3972
83	70	316	10	208	165	122	0.3861
59	46	476	26	279	231	183	0.3845
84	73	346	51	213	172	131	0.3786
55	51	588	40	481	345	209	0.3554
31	1	860	33	345	325	301	0.3500
5	3	509	30	511	340	169	0.3320
78	79	107	9	65	50	35	0.3271
76	89	77	65	102	63	24	0.3117
77	75	782	34	248	238	228	0.2916
40	41	560	40	556	355	154	0.2750
32	21	758	46	716	462	208	0.2744
23	30	1037	50	680	472	264	0.2546
64	60	349	42	219	150	81	0.2921
86	27	321	23	327	198	69	0.2150
2	86	550	29	321	215	109	0.1982
89	76	259	17	77	63	49	0.1892
11	84	665	35	346	226	106	0.1594
7	75	384	25	248	154	60	0.1562
81	23	1084	64	1037	584	191	0.1208
30	25	680	20	399	237	75	0.1203
75	97	248	66	79	52	25	0.1008
88	79	353	13	181	106	31	0.0878
87	60	328	42	206	115	24	0.0732
62	46	364	11	72	48	24	0.0659
79	78	65	9	107	50	-7	-0.1077

TABLE OF MAXIMA. VERTICAL 1 PAGE 1

REF	INP	NORM	LINE	MASK	P	UNMAT	MATCH
101	22	345	18	383	315	247	0.7159
102	3	550	31	511	289	67	0.1218
103	6	511	28	499	321	143	0.2798
104	1	490	28	345	312	279	0.5694
105	6	509	29	499	359	219	0.4303
106	73	499	30	351	276	201	0.4028
107	75	384	25	248	158	68	0.1771
108	3	696	31	511	457	403	0.5790
109	10	595	30	566	430	294	0.4941
110	6	566	29	499	396	293	0.5177
111	84	665	35	346	227	108	0.1624
112	38	819	59	646	629	612	0.7528
113	18	831	41	646	565	484	0.5824
114	19	510	17	469	401	333	0.6529
115	36	828	59	852	636	420	0.5072
116	35	661	17	382	349	316	0.4781
117	21	1252	71	718	687	656	0.5240
118	28	646	33	413	305	197	0.3050
119	24	974	50	994	816	638	0.6550
120	19	912	49	974	760	546	0.5987
121	17	718	44	864	640	416	0.5794
122	15	682	53	805	572	339	0.4971
123	30	1037	50	680	479	278	0.2681
124	39	994	54	1009	807	605	0.4087
125	41	788	45	626	442	258	0.3274
126	24	812	50	994	749	504	0.6207
127	14	790	36	510	483	456	0.6247
128	25	587	48	712	501	290	0.4940
129	14	642	48	467	421	375	0.5841
130	25	680	21	408	236	64	0.0941
131	1	860	33	345	310	275	0.3198
132	25	758	68	389	275	161	0.2124
133	24	1039	50	994	881	768	0.7392
134	36	662	96	396	361	326	0.4924
135	36	1232	70	1213	940	667	0.5414
136	35	1213	66	1232	906	580	0.4782
137	39	821	53	605	551	497	0.6054
138	39	1000	39	605	518	431	0.4910
139	38	605	59	646	580	514	0.8496
140	41	560	40	556	387	218	0.3893
141	25	1007	67	788	584	380	0.3774
142	34	786	41	656	490	324	0.4122
143	50	422	26	327	269	211	0.5000
144	73	585	31	356	312	268	0.4581
145	69	392	29	364	297	230	0.5867
146	67	279	14	256	215	194	0.6953
147	54	413	32	420	331	242	0.5860
148	60	388	26	302	250	198	0.5103
149	53	755	52	426	383	340	0.4503
150	72	327	26	351	219	87	0.2661
151	52	481	31	588	460	332	0.6902
152	51	588	32	481	372	263	0.4473
153	49	426	32	522	391	260	0.6103
154	47	420	36	411	304	197	0.4690
155	51	588	40	481	327	173	0.2942

TABLE OF MAXIMA. VERTICAL 1 PAGE 2

REF	INP	NORM	LINE	MASK	P	UNMAT	MATCH
156	58	461	32	493	419	345	0.7484
157	73	390	30	383	325	267	0.6846
158	67	493	50	483	410	337	0.6836
159	46	476	26	279	227	175	0.3676
160	48	302	27	388	270	152	0.5033
161	54	316	21	356	295	154	0.4873
162	46	364	11	72	44	16	0.0440
163	67	778	45	677	476	275	0.3535
164	53	349	32	426	255	84	0.2407
165	68	534	36	506	479	452	0.8464
166	67	397	66	231	201	171	0.4307
167	68	707	53	720	581	442	0.6252
168	67	720	49	707	617	527	0.7319
169	71	395	37	362	314	266	0.6734
170	71	605	28	362	317	272	0.4496
171	69	362	28	395	296	197	0.5442
172	50	351	26	327	239	151	0.4302
173	53	569	31	426	323	220	0.3866
174	56	422	31	461	396	211	0.5000
175	37	248	66	79	51	23	0.0927
176	89	77	66	98	60	22	0.2857
177	75	782	34	248	246	244	0.3120
178	82	107	10	148	96	44	0.4112
179	78	65	9	107	41	-25	-0.3846
180	15	114	55	73	62	51	0.4474
181	85	1084	19	235	162	89	0.0821
182	79	148	10	65	56	47	0.3176
183	70	316	10	208	163	118	0.3734
184	73	346	51	213	172	131	0.3786
185	1	235	12	325	210	95	0.4043
186	27	321	24	339	205	71	0.2212
187	69	328	57	57	39	21	0.0640
188	46	353	10	62	44	26	0.0737
189	76	259	17	77	48	19	0.0734

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REF	INP	NORM	LINE	MASK	P	UNMAT	MATCH
139	38	605	59	646	580	514	0.8496
165	68	594	36	506	479	452	0.8464
112	38	813	59	646	629	612	0.7528
156	58	461	32	493	419	345	0.7484
133	24	1039	50	994	881	768	0.7392
168	67	720	49	707	617	527	0.7319
101	22	945	18	389	315	247	0.7159
146	67	279	14	296	215	194	0.6953
151	52	481	31	588	460	332	0.6902
157	73	390	30	389	325	267	0.6846
158	67	493	50	483	410	337	0.6836
169	71	395	37	382	314	266	0.6794
119	24	974	50	994	816	638	0.6950
114	19	510	17	469	401	333	0.6529
167	68	707	59	720	581	442	0.6252
127	14	730	36	510	483	456	0.6247
126	24	812	50	994	749	504	0.6207
153	49	426	32	522	391	260	0.6105
124	33	994	54	1009	807	605	0.6087
137	39	821	53	605	551	497	0.6054
120	19	912	49	974	760	546	0.5987
145	69	392	29	364	297	230	0.5867
147	54	413	32	420	331	242	0.5860
129	14	642	48	467	421	375	0.5841
113	18	831	41	646	565	484	0.5824
121	17	718	44	864	640	416	0.5794
108	3	696	31	511	457	403	0.5790
104	1	490	28	345	312	279	0.5694
171	69	362	28	395	296	197	0.5442
135	36	1232	70	1213	940	667	0.5414
117	21	1252	71	718	687	656	0.5240
110	6	566	29	499	396	293	0.5177
148	60	388	26	302	250	198	0.5103
115	36	828	59	892	636	420	0.5072
160	48	302	27	388	270	192	0.5093
143	50	422	26	327	269	211	0.5000
174	56	422	31	461	336	211	0.5000
122	15	682	53	805	572	339	0.4971
109	10	595	30	566	430	294	0.4941
128	25	587	48	712	501	290	0.4940
134	36	662	96	396	361	326	0.4924
161	54	316	21	356	255	154	0.4873
136	35	1213	66	1292	906	580	0.4782
116	35	661	17	342	349	316	0.4781
154	47	420	36	411	304	197	0.4690
144	73	585	31	356	312	268	0.4581
149	53	755	52	426	383	340	0.4503
170	71	605	28	362	317	272	0.4496
180	15	114	55	73	62	51	0.4474
152	51	588	32	481	372	263	0.4473
138	39	1000	39	605	518	451	0.4310
166	67	397	66	231	201	171	0.4307
105	6	509	29	499	359	219	0.4303
172	50	351	26	327	239	151	0.4302
142	34	786	41	656	490	324	0.4122

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REF	INP	NORM	LINE	MASK	P	UNMAT	MATCH
178	82	107	10	148	96	44	0.4112
185	1	235	12	325	210	95	0.4043
106	73	499	30	351	276	201	0.4028
140	41	560	40	556	387	218	0.3893
173	53	569	31	426	323	220	0.3866
184	73	346	51	213	172	131	0.3786
141	25	1007	67	788	584	380	0.3774
183	70	316	10	208	163	118	0.3734
159	46	476	26	279	227	175	0.3676
169	67	778	45	677	476	275	0.3595
125	41	788	45	626	442	258	0.3274
131	1	860	33	345	310	275	0.3198
182	79	148	10	65	56	47	0.3176
177	75	782	34	248	246	244	0.3120
118	28	646	33	413	305	197	0.3050
155	51	588	40	481	327	173	0.2942
176	89	77	66	98	60	22	0.2857
109	6	511	28	499	321	143	0.2798
123	30	1037	50	680	479	278	0.2681
150	72	327	26	351	219	87	0.2661
164	53	349	32	426	255	84	0.2407
186	27	321	24	339	205	71	0.2212
132	25	758	68	389	275	161	0.2124
107	75	384	25	248	158	68	0.1771
111	84	665	35	346	227	108	0.1624
102	9	550	31	511	289	67	0.1218
190	29	680	21	408	236	64	0.0941
175	37	248	66	79	51	23	0.0927
181	85	1084	19	235	162	89	0.0821
188	46	359	10	62	44	26	0.0737
189	76	259	17	77	48	19	0.0734
187	69	328	57	57	39	21	0.0640
162	46	364	11	72	44	16	0.0440
179	78	65	9	107	41	-25	-0.3846

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REF	INP	NORM	LINE	MASK	P	UNMAT	MATCH
1	22	345	18	383	306	229	0.6638
2	22	550	54	309	184	59	0.1073
3	6	511	29	499	309	119	0.2329
4	1	490	28	345	298	251	0.5122
5	73	509	30	356	269	182	0.3576
6	73	499	30	351	247	143	0.2866
7	75	384	25	248	157	66	0.1719
8	3	696	30	511	419	327	0.4698
9	10	595	30	566	396	226	0.3798
10	6	566	30	499	363	227	0.4011
11	84	665	36	346	226	106	0.1594
12	38	813	59	646	573	500	0.6150
13	38	831	59	649	533	417	0.5018
14	29	510	29	571	441	311	0.6098
15	36	828	54	863	598	333	0.4022
16	35	661	17	382	323	264	0.3994
17	21	1252	71	718	622	526	0.4201
18	25	646	38	613	411	209	0.3235
19	24	974	50	994	761	528	0.5421
20	19	912	48	974	700	426	0.4671
21	41	718	66	720	511	302	0.4206
22	36	682	100	400	345	290	0.4252
23	30	1037	49	680	464	248	0.2392
24	33	994	54	1009	751	493	0.4960
25	41	788	45	626	381	136	0.1726
26	24	812	50	994	699	404	0.4975
27	14	730	36	510	448	386	0.5288
28	25	587	48	712	504	296	0.5043
29	14	642	48	467	389	311	0.4844
30	84	680	24	346	203	60	0.0882
31	1	860	33	345	300	255	0.2965
32	25	758	68	389	261	133	0.1755
33	24	1039	50	994	825	656	0.6314
34	36	662	96	396	341	286	0.4320
35	36	1232	70	1213	852	491	0.3985
36	35	1213	66	1232	820	408	0.3364
37	38	821	73	649	551	453	0.5518
38	39	1000	39	605	448	291	0.2910
39	38	605	59	646	518	390	0.6446
40	41	560	40	556	374	192	0.3429
41	25	1007	67	788	611	494	0.4910
42	36	786	93	396	341	286	0.3699
43	50	422	25	327	244	161	0.3815
44	6	585	30	499	343	187	0.3197
45	71	392	29	362	266	170	0.4337
46	54	279	13	241	205	169	0.6057
47	54	413	32	420	299	178	0.4310
48	60	388	26	302	209	116	0.2990
49	53	755	52	426	328	230	0.3046
50	66	327	43	166	106	46	0.1407
51	58	481	32	493	372	251	0.5218
52	56	588	31	461	316	171	0.2908
53	49	426	32	522	334	146	0.3427
54	67	420	69	227	180	133	0.3167
55	66	588	39	397	268	139	0.2364

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REF	INP	NORM	LINE	MASK	P	UNMAT	MATCH
56	58	461	32	493	380	267	0.5792
57	73	390	30	383	294	205	0.5256
58	67	493	50	483	373	263	0.5335
59	46	476	26	279	214	149	0.3130
60	48	302	27	388	228	68	0.2252
61	54	316	21	356	230	104	0.3291
62	46	364	11	72	40	8	0.0220
63	67	778	45	677	443	209	0.2686
64	60	349	42	219	135	51	0.1461
65	67	534	50	503	433	363	0.6798
66	67	397	66	231	183	135	0.3401
67	68	707	53	720	512	304	0.4300
68	67	720	49	707	550	393	0.5458
69	71	395	37	362	266	170	0.4304
70	71	605	28	362	269	176	0.2909
71	69	362	28	395	247	99	0.2735
72	50	351	26	327	205	83	0.2365
73	53	569	31	426	296	166	0.2917
74	51	422	32	481	321	161	0.3815
75	97	248	65	84	52	20	0.0806
76	89	77	66	98	44	-10	-0.1299
77	75	782	34	248	248	238	0.3043
78	82	107	10	148	98	48	0.4486
79	89	65	1	41	0	-41	-0.6308
80	79	114	10	65	62	59	0.5175
81	85	1084	19	235	154	73	0.0673
82	79	148	10	65	59	41	0.2770
83	70	316	10	208	161	114	0.3608
84	73	346	51	213	172	131	0.3786
85	34	235	39	231	163	95	0.4043
86	27	321	24	399	187	35	0.1090
87	69	328	56	63	41	19	0.0579
88	46	353	11	66	46	26	0.0737
89	74	259	96	7	0	-7	-0.0270

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REF	INP	NORM	LINE	MASK	P	UNMAT	MATCH
65	67	534	50	503	433	363	0.6798
1	22	345	18	383	306	229	0.6638
39	38	605	59	646	518	390	0.6446
33	24	1039	50	994	829	656	0.6314
12	38	813	59	646	573	500	0.6150
14	29	510	29	571	441	311	0.6098
46	54	279	13	241	205	169	0.6057
56	58	461	32	493	380	267	0.5792
37	38	821	73	649	551	453	0.5518
68	67	720	49	707	550	393	0.5458
19	24	974	50	994	761	528	0.5421
58	67	493	50	483	373	263	0.5395
27	14	730	36	510	448	386	0.5288
57	73	390	30	383	294	205	0.5256
51	58	481	32	493	372	251	0.5218
80	79	114	10	65	62	59	0.5175
4	1	490	28	345	298	251	0.5122
28	25	587	48	712	504	296	0.5045
13	38	831	59	649	533	417	0.5018
26	24	812	50	994	699	404	0.4975
24	33	994	54	1009	751	493	0.4960
29	14	642	48	467	389	311	0.4844
8	9	696	30	511	419	327	0.4698
20	19	912	48	974	700	426	0.4671
78	82	107	10	148	98	48	0.4486
45	71	392	29	362	266	170	0.4337
34	36	662	96	396	341	286	0.4320
47	54	413	32	420	299	178	0.4310
41	25	1007	67	788	611	434	0.4310
69	71	395	37	362	266	170	0.4304
67	68	707	53	720	512	304	0.4300
22	36	682	100	400	345	290	0.4252
21	41	718	66	720	511	302	0.4206
17	21	1252	71	718	622	526	0.4201
85	94	235	39	231	163	95	0.4043
15	36	828	54	863	598	333	0.4022
10	6	566	30	499	363	227	0.4011
16	35	661	17	382	323	264	0.3994
35	36	1292	70	1213	852	491	0.3985
43	50	422	25	327	244	161	0.3815
74	51	422	32	481	321	161	0.3815
9	10	595	30	566	396	226	0.3798
84	79	346	51	213	172	131	0.3786
42	36	786	93	396	341	286	0.3639
83	70	316	10	208	161	114	0.3608
5	79	509	30	356	269	182	0.3576
40	41	560	40	556	374	192	0.3429
53	49	426	32	522	334	146	0.3427
66	67	397	66	231	183	135	0.3401
36	35	1213	66	1232	820	408	0.3364
61	54	316	21	356	230	104	0.3291
18	25	646	38	619	411	209	0.3235
44	6	585	30	499	343	187	0.3197
54	67	420	69	227	180	133	0.3167
59	46	476	26	279	214	149	0.3130

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REF	INP	NORM	°LINE	MASK	P	UNMAT	MATCH
49	53	755	52	426	328	230	0.3046
77	75	782	34	248	243	238	0.3049
48	60	388	26	302	209	116	0.2990
31	1	860	33	345	300	255	0.2965
73	53	569	31	426	296	166	0.2917
38	39	1000	39	605	448	291	0.2910
70	71	605	28	362	269	176	0.2909
52	56	588	31	461	316	171	0.2908
6	73	499	30	351	247	143	0.2866
82	79	148	10	65	53	41	0.2770
71	69	362	28	395	247	99	0.2735
63	67	778	45	677	443	209	0.2686
23	30	1037	49	680	464	248	0.2392
72	50	351	26	327	205	83	0.2365
55	66	588	39	397	268	139	0.2364
9	6	511	29	499	309	119	0.2329
60	48	302	27	388	228	68	0.2252
32	25	758	68	389	261	133	0.1755
25	41	788	45	626	381	136	0.1726
7	75	384	25	248	157	66	0.1719
11	84	665	36	346	226	106	0.1594
64	60	349	42	219	135	51	0.1461
50	66	327	43	166	106	46	0.1407
86	27	321	24	339	187	35	0.1090
2	22	550	54	309	184	59	0.1073
30	84	680	24	346	209	60	0.0882
75	37	248	65	84	52	20	0.0806
88	46	359	11	66	46	26	0.0797
81	85	1084	19	295	154	73	0.0673
87	69	328	56	63	41	19	0.0579
62	46	364	11	72	40	8	0.0220
89	74	259	96	7	0	-7	-0.0270
76	89	77	66	98	44	-10	-0.1299
79	89	65	1	41	0	-41	-0.6308

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REF	INP	NORM	LINE	MASK	P	UNMAT	MATCH
101	22	345	18	383	331	279	0.8087
102	86	550	29	321	252	183	0.3927
103	8	511	30	696	521	346	0.6771
104	1	490	28	345	329	313	0.6388
105	6	509	30	499	385	271	0.5324
106	10	499	30	566	446	326	0.6533
107	75	384	26	248	177	106	0.2760
108	3	696	30	511	488	465	0.6681
109	10	595	30	566	480	394	0.6622
110	9	566	31	595	491	387	0.6837
111	4	665	39	490	321	152	0.2286
112	13	813	40	831	739	647	0.7958
113	12	831	40	813	746	679	0.8171
114	29	510	29	571	495	419	0.8216
115	36	828	53	852	696	540	0.6522
116	13	661	41	831	642	453	0.6853
117	21	1252	71	718	711	704	0.5623
118	13	646	36	816	614	412	0.6378
119	24	974	50	994	888	782	0.8029
120	19	912	49	974	881	788	0.8640
121	17	718	44	864	774	684	0.9526
122	15	682	53	805	646	487	0.7141
123	30	1037	50	680	521	362	0.3491
124	33	994	54	1009	912	815	0.8199
125	41	788	45	626	584	542	0.6878
126	33	812	54	994	819	644	0.7931
127	14	730	36	510	503	496	0.6795
128	41	587	46	595	470	345	0.5877
129	14	442	48	467	457	447	0.6963
130	25	680	20	399	259	119	0.1750
131	1	860	33	945	930	915	0.3663
132	21	758	46	716	512	308	0.4063
133	24	1039	50	994	896	798	0.7680
134	56	662	96	396	382	368	0.5559
135	36	1232	70	1213	1037	861	0.6989
136	35	1213	66	1232	1011	790	0.6513
137	39	821	53	605	590	575	0.7004
138	39	1000	39	605	605	605	0.6050
139	38	605	59	646	633	620	1.0248
140	41	560	40	556	412	268	0.4786
141	21	1007	45	718	622	526	0.5223
142	94	786	41	656	551	446	0.5674
143	50	422	25	327	301	275	0.6517
144	57	585	30	390	383	376	0.6427
145	69	392	29	364	329	294	0.7500
146	61	279	21	285	259	233	0.8351
147	54	413	32	420	371	322	0.7797
148	60	388	26	302	295	288	0.7423
149	53	755	52	426	426	426	0.5642
150	72	327	26	351	294	237	0.7248
151	56	481	31	461	444	427	0.8877
152	51	588	32	481	471	461	0.7840
153	49	426	32	522	474	426	1.0000
154	47	420	36	411	350	289	0.6881
155	51	588	40	481	367	253	0.4303

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REF	INP	NORM	LINE	MASK	P	UNMAT	MATCH
156	58	461	32	493	460	427	0.9262
157	73	390	30	383	338	293	0.7513
158	65	493	36	534	473	412	0.8357
159	57	476	31	390	312	234	0.4916
160	48	302	27	388	315	242	0.8013
161	46	316	34	278	242	206	0.6519
162	54	364	44	222	191	40	0.1099
163	67	778	45	677	542	407	0.5231
164	53	349	32	426	302	178	0.5100
165	68	534	36	506	494	482	0.9026
166	58	397	31	493	369	245	0.6171
167	68	707	53	720	661	602	0.8515
168	67	720	49	707	681	655	0.9097
169	71	395	37	362	362	362	0.9165
170	71	605	28	362	361	360	0.9950
171	69	362	28	395	348	301	0.8315
172	50	351	26	327	286	245	0.6980
173	57	569	45	390	367	344	0.6046
174	56	422	31	461	381	301	0.7139
175	11	248	44	304	175	46	0.1855
176	89	77	65	102	64	26	0.3377
177	75	782	34	248	246	244	0.9120
178	82	107	10	148	104	60	0.5607
179	78	65	9	107	53	-1	-0.0154
180	15	114	55	79	64	55	0.4825
181	23	1084	64	1037	675	313	0.2887
182	78	148	9	107	96	85	0.5743
183	54	316	10	222	177	132	0.4177
184	51	346	37	222	181	140	0.4046
185	1	235	12	325	236	147	0.6255
186	27	321	24	339	242	145	0.4517
187	60	328	42	206	143	80	0.2439
188	73	353	13	181	133	85	0.2408
189	76	259	16	77	77	77	0.2973

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REF	INP	NORM	LINE	MASK	P	UNMAT	MATCH
139	38	605	59	646	633	620	1.0248
153	49	426	32	522	474	426	1.0000
121	17	718	44	864	774	684	0.9526
156	58	461	32	499	460	427	0.9262
169	71	395	37	362	362	362	0.9165
168	67	720	49	707	681	655	0.9097
165	68	534	36	506	494	482	0.9026
151	56	481	31	461	444	427	0.8877
120	19	912	49	974	881	788	0.8640
167	68	707	53	720	661	602	0.8515
158	65	493	36	534	473	412	0.8357
146	61	279	21	285	259	233	0.8351
171	69	362	28	395	348	301	0.8315
114	29	510	29	571	495	419	0.8216
124	33	994	54	1009	912	815	0.8199
113	12	831	40	813	746	679	0.8171
101	22	345	18	383	331	279	0.8087
119	24	974	50	994	888	782	0.8029
160	48	302	27	388	315	242	0.8013
112	13	813	40	831	739	647	0.7958
126	33	812	54	994	819	644	0.7931
152	51	586	32	481	471	461	0.7840
147	54	413	32	420	371	322	0.7797
133	24	1039	50	994	896	798	0.7680
157	73	390	30	383	338	293	0.7513
145	69	392	29	364	329	294	0.7500
148	60	388	26	302	295	288	0.7423
150	72	327	26	351	294	237	0.7248
122	15	682	53	805	646	487	0.7141
174	56	422	31	461	381	301	0.7133
137	39	821	53	605	590	575	0.7004
135	36	1232	70	1213	1037	861	0.6989
172	50	351	26	327	286	245	0.6980
129	14	642	48	467	457	447	0.6963
154	47	420	36	411	350	289	0.6881
125	41	788	45	626	584	542	0.6878
116	13	661	41	831	642	453	0.6853
110	9	566	31	595	491	387	0.6837
127	14	730	36	510	503	496	0.6795
103	8	511	30	696	521	346	0.6771
108	3	696	30	511	488	465	0.6681
109	10	595	30	566	480	394	0.6622
106	10	499	30	566	446	326	0.6595
115	36	828	59	852	696	540	0.6522
161	46	316	34	278	242	206	0.6519
143	50	422	25	327	301	275	0.6517
136	35	1219	66	1292	1011	790	0.6513
144	57	585	30	390	383	376	0.6427
104	1	490	28	345	329	313	0.6388
118	13	646	36	816	614	412	0.6378
185	1	235	12	325	236	147	0.6295
166	58	397	31	493	369	245	0.6171
138	39	1000	39	605	605	605	0.6050
173	57	569	45	390	367	344	0.6046
170	71	605	28	362	361	360	0.5950

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REF	INP	NORM	LINE	MASK	P	UNMAT	MATCH
120	41	587	46	595	470	945	0.5877
182	78	148	9	107	96	85	0.5743
142	94	786	41	656	551	446	0.5674
149	53	755	52	426	426	426	0.5642
117	21	1252	71	718	711	704	0.5623
178	82	107	10	148	104	60	0.5607
134	96	662	96	396	382	368	0.5559
105	6	509	90	499	385	271	0.5324
163	67	778	45	677	542	407	0.5231
141	21	1007	45	718	622	526	0.5223
164	53	349	32	426	302	178	0.5100
159	57	476	31	390	312	234	0.4916
180	15	114	55	73	64	55	0.4825
140	41	560	40	556	412	268	0.4786
186	27	321	24	339	242	145	0.4517
155	51	588	40	481	367	253	0.4503
183	54	316	10	222	177	132	0.4177
132	21	758	46	716	512	308	0.4065
184	51	346	37	222	181	140	0.4046
131	1	860	33	345	330	315	0.3663
123	30	1037	50	680	521	362	0.3491
176	89	77	65	102	64	26	0.3377
102	86	550	29	321	252	183	0.3327
177	75	782	34	248	246	244	0.3120
189	76	259	16	77	77	77	0.2973
181	23	1084	64	1037	675	313	0.2887
107	75	384	26	248	177	106	0.2760
187	60	328	42	206	143	80	0.2439
188	73	353	13	181	133	85	0.2408
111	4	665	39	490	321	152	0.2286
175	11	248	44	304	175	46	0.1855
130	25	680	20	399	259	119	0.1750
162	54	364	44	222	131	40	0.1099
179	78	65	9	107	53	-1	-0.0154

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REF	INP	NORM	LINE	MASK	P	UNMAT	MATCH
201	22	345	18	383	338	293	0.8493
202	9	550	30	595	415	235	0.4273
203	8	511	30	696	568	440	0.8611
204	19	490	29	519	420	321	0.6551
205	6	509	30	499	412	325	0.6385
206	5	499	30	509	443	377	0.7555
207	75	384	26	248	200	152	0.3958
208	3	696	30	511	500	489	0.7026
209	10	595	30	566	494	422	0.7092
210	9	566	31	595	509	423	0.7473
211	52	665	37	588	416	244	0.3669
212	13	813	40	831	767	703	0.8647
213	12	831	40	813	776	739	0.8893
214	29	510	29	571	530	489	0.9588
215	36	828	53	852	727	592	0.7150
216	19	661	41	831	674	517	0.7821
217	21	1252	71	718	715	712	0.9687
218	13	646	36	816	641	466	0.7214
219	24	974	50	994	900	806	0.8275
220	19	912	49	974	906	838	0.9189
221	17	718	44	864	788	712	0.9916
222	15	682	53	805	668	531	0.7786
223	30	1037	50	680	545	410	0.3954
224	33	994	54	1009	916	823	0.8280
225	41	788	45	626	612	598	0.7589
226	33	812	54	994	830	666	0.8202
227	29	730	29	559	534	509	0.6973
228	25	587	48	712	573	434	0.7394
229	14	642	48	467	458	449	0.6994
230	23	680	58	941	558	175	0.2574
231	1	860	33	345	341	337	0.3919
232	17	758	66	933	663	393	0.5185
233	24	1039	90	994	898	802	0.7719
234	36	662	96	396	385	374	0.5650
235	36	1232	70	1219	1049	885	0.7183
236	35	1219	66	1232	1024	816	0.6727
237	12	821	54	813	715	617	0.7515
238	39	1000	39	605	605	605	0.6050
239	38	605	59	646	641	636	1.0512
240	18	560	39	646	488	330	0.5893
241	21	1007	45	718	658	598	0.5938
242	17	786	68	879	690	501	0.6374
243	50	422	25	327	314	301	0.7133
244	57	585	30	390	389	388	0.6632
245	67	392	32	484	412	340	0.8673
246	61	279	21	285	265	245	0.8781
247	54	419	32	420	376	332	0.8039
248	60	388	26	302	298	294	0.7577
249	59	755	52	426	426	426	0.5642
250	43	327	28	422	354	286	0.8746
251	56	481	31	461	448	435	0.9044
252	51	588	32	481	477	473	0.8044
253	49	426	32	522	477	432	1.0141
254	47	420	36	411	358	305	0.7262
255	51	588	40	481	387	293	0.4983

TABLE OF MAXIMA. VERTICAL 0 PAGE 2

REF	INP	NORM	LINE	MASK	P	UNMAT	MATCH
256	58	461	32	493	462	431	0.9349
257	73	390	30	383	344	305	0.7821
258	65	493	36	534	480	426	0.8641
259	58	476	32	493	378	263	0.5525
260	48	302	27	388	319	250	0.8278
261	46	316	34	278	243	208	0.6582
262	54	364	44	222	148	74	0.2099
263	67	778	45	677	570	463	0.5951
264	49	349	50	524	380	236	0.6762
265	68	534	36	506	494	482	0.9026
266	58	397	31	493	479	265	0.6675
267	68	707	53	720	665	610	0.8628
268	67	720	49	707	683	659	0.9153
269	70	395	51	404	385	366	0.9266
270	71	605	28	362	362	362	0.5989
271	69	362	28	395	348	301	0.8315
272	50	351	26	327	310	293	0.8348
273	57	569	45	390	383	376	0.6608
274	56	422	31	461	399	337	0.7986
275	11	248	44	304	187	70	0.2823
276	99	77	65	102	64	26	0.3377
277	75	782	34	248	248	248	0.3171
278	82	107	10	148	121	94	0.8785
279	80	65	9	114	63	12	0.1846
280	15	114	54	80	71	62	0.5439
281	23	1084	64	1037	742	447	0.4124
282	78	148	9	107	102	97	0.6554
283	54	316	10	222	182	142	0.4494
284	77	346	37	319	237	155	0.4480
285	38	235	19	333	257	181	0.7702
286	27	321	24	339	258	177	0.5514
287	60	428	30	302	218	134	0.4085
288	49	353	46	546	347	148	0.4193
289	76	259	16	77	77	77	0.2973

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REF	INP	NORM	LINE	MASK	P	UNMAT	MATCH
239	38	605	59	646	641	636	1.0512
253	49	426	32	522	477	432	1.0141
221	17	718	44	864	788	712	0.9916
214	29	510	29	571	530	489	0.9588
256	58	461	32	493	462	431	0.9349
269	70	395	51	404	385	366	0.9266
220	19	912	49	974	906	838	0.9189
268	67	720	49	707	683	659	0.9153
251	56	481	31	461	448	435	0.9044
265	68	534	36	506	494	482	0.9026
219	12	831	40	813	776	739	0.8893
278	82	107	10	148	121	94	0.8785
246	61	279	21	285	265	245	0.8781
250	43	327	28	422	354	286	0.8746
245	67	392	32	484	412	340	0.8673
212	19	813	40	831	767	703	0.8647
258	65	493	36	534	480	426	0.8641
267	68	707	53	720	665	610	0.8628
203	8	511	30	696	568	440	0.8611
201	22	345	16	383	338	293	0.8493
272	50	351	26	327	310	293	0.8348
271	69	362	28	395	348	301	0.8315
224	33	994	54	1009	916	823	0.8280
260	48	302	27	388	319	250	0.8278
219	24	974	50	994	900	806	0.8275
226	33	812	54	994	830	666	0.8202
252	51	588	32	481	477	473	0.8044
247	54	413	32	420	376	332	0.8039
274	56	422	31	461	399	337	0.7986
216	13	661	41	831	674	517	0.7821
257	73	390	30	383	344	305	0.7821
222	15	682	53	805	668	531	0.7786
233	24	1039	50	994	898	802	0.7719
285	38	235	13	333	257	181	0.7702
229	41	788	45	626	612	598	0.7589
248	60	388	26	302	298	294	0.7577
206	5	499	30	509	443	377	0.7555
237	12	821	54	813	715	617	0.7515
210	9	566	31	595	509	423	0.7479
228	25	587	48	712	573	434	0.7394
254	47	420	36	411	358	305	0.7262
218	13	646	36	816	641	466	0.7214
295	36	1232	70	1213	1049	885	0.7183
215	36	828	53	852	722	592	0.7150
243	50	422	25	327	314	301	0.7133
209	10	595	30	566	494	422	0.7092
208	3	696	30	511	500	489	0.7026
229	14	642	48	467	458	449	0.6994
227	29	790	29	559	534	509	0.6973
284	49	349	50	524	380	236	0.6762
236	35	1213	66	1232	1024	816	0.6727
266	58	397	31	493	379	265	0.6675
244	57	585	30	390	389	388	0.6692
273	57	569	45	390	383	376	0.6608
261	46	916	34	278	249	208	0.6582

TABLE OF MAXIMA. VERTICAL 0 PAGE 2

REF	INP	NORM	LINE	MASK	P	UNMAT	MATCH
282	78	148	9	107	102	97	0.6554
204	19	490	29	519	420	321	0.6551
205	6	509	30	499	412	325	0.6385
242	17	786	68	879	690	501	0.6374
238	39	1000	39	605	605	605	0.6050
270	71	605	28	362	362	362	0.5989
263	67	778	45	677	570	463	0.5951
241	21	1007	45	718	658	598	0.5938
240	18	560	39	646	488	330	0.5893
217	21	1252	71	718	715	712	0.5687
234	36	662	96	396	385	374	0.5650
249	53	755	52	426	426	426	0.5642
259	58	476	32	493	378	263	0.5525
286	27	321	24	339	258	177	0.5514
280	15	114	54	80	71	62	0.5439
232	17	758	66	933	663	393	0.5185
255	51	588	40	481	387	294	0.4989
283	54	316	10	222	182	142	0.4494
284	77	346	37	319	237	155	0.4480
202	9	550	30	595	415	235	0.4273
288	49	353	46	546	347	148	0.4193
281	23	1084	64	1037	742	447	0.4124
287	60	328	30	302	218	134	0.4085
207	75	384	26	248	200	152	0.3958
223	90	1037	50	680	545	410	0.3954
231	1	860	33	345	341	337	0.3919
211	52	665	37	588	416	244	0.3669
276	89	77	65	102	64	26	0.3377
277	75	782	34	248	248	248	0.3171
289	76	259	16	77	77	77	0.2973
275	11	248	44	304	187	70	0.2829
230	23	680	58	941	558	175	0.2574
262	54	364	44	222	148	74	0.2033
279	80	65	9	114	63	12	0.1846

CATALOGUE FILE CARD

Rome Air Development Center, Griffiss AF Base, NY Rpt No. RADC-TDR-62-472, ENGINEERING ANALYSIS AND DIGITAL SIMULATION OF BAIRD-ATOMIC PRINT READER Final Rpt, 3 Sept 62, 45 pp Unclassified Report The Optical Russian Print Reader (Converter Group, Print-To--Digital AN/GSA-29) has been assembled, the front end optics aligned, and the line following servo system analyzed with the assistance of Baird-Atomic personnel. An IBM 7090 simulation shows that the basic masking technique used for an idealized electro-optical system yields adequate discrimination levels only for very high quality characters and for very close tolerance on text registration. The report contains a detailed description of the servo analysis and masking techniques simulation; it also includes error rate tabulations based on input text quality and proposed mask alterations.	1. Pattern Recognition 2. Analog-to-Digital Converter I. Project 4599 Task 459902 II. Cont AF 30(602)-2080 III. IBM Corp. Thomas J. Watson Research Center, Yorktown Heights, N. Y. IV. In ASTIA collection	Rome Air Development Center, Griffiss AF Base, NY Rpt No. RADC-TDR-62-472, ENGINEERING ANALYSIS AND DIGITAL SIMULATION OF BAIRD-ATOMIC PRINT READER Final Rpt, 3 Sept 62, 45 pp Unclassified Report The Optical Russian Print Reader (Converter Group, Print-To-Digital AN/GSA-29) has been assembled, the front end optics aligned, and the line following servo system analyzed with the assistance of Baird-Atomic personnel. An IBM 7090 simulation shows that the basic masking technique used for an idealized electro-optical system yields adequate discrimination levels only for very high quality characters and for very close tolerances on text registration. The report contains a detailed description of the servo analysis and masking techaique simulation; it also includes error rate tabulations based on input text quality and proposed mask alterations	1. Pattern Recognition 2. Analog-to-Digital Converter I. Project 4599, Task 459902 II. Cont AF 30(602)2080 III. IBM Corp. Thomas J. Watson Research Center, Yorktown Heights, N. Y. IV. In ASTIA collection
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